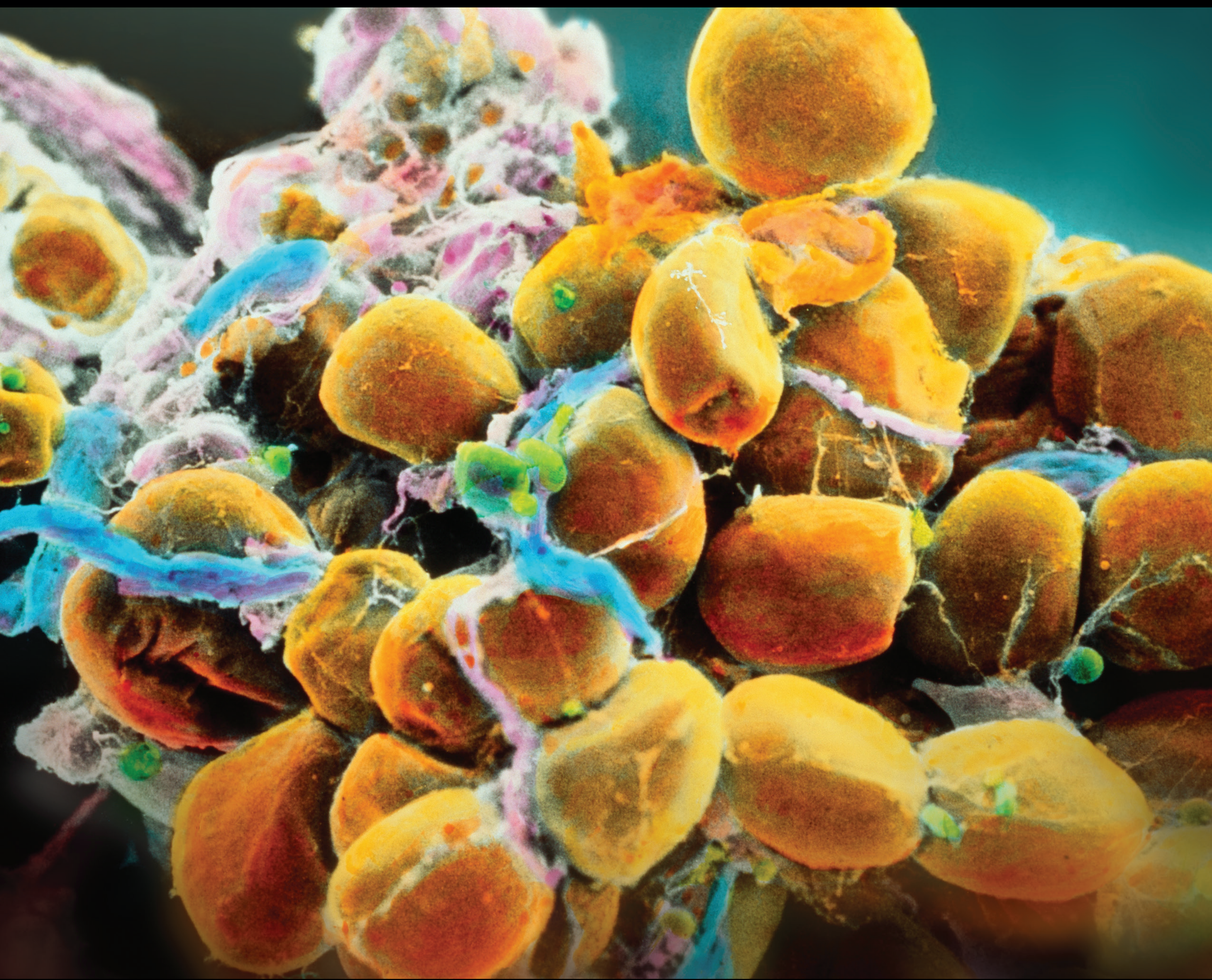
Journal of Obesity

The Effect of Early Life Factors and Early Interventions on Childhood Overweight and Obesity

Guest Editors: Li Ming Wen, Chris Rissel, and Gengsheng He



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Editorial Board

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Editorial

The Effect of Early Life Factors and Early Interventions on Childhood Overweight and Obesity

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The global obesity epidemic continues to be one of the major health burdens on society, which directly affects our younger generation. Worldwide, more than 40 million children under the age of five were overweight with a global prevalence of overweight being 6.7% in 2010 [1]. The rates of overweight and obesity have been dramatically increasing in some developing countries such as China [2] over recent years. This highlights the need for a better understanding of the effect of early life factors on overweight and obesity and, more importantly, developing effective early interventions.

Research evidence has already showed that some early infant feeding practices, including breastfeeding and the timing of the introduction of solids as well as children's eating habits and television viewing time, are among the most identifiable factors contributing to early onset of childhood obesity [3]. However, these risk factors for overweight and obesity are just the tip of the iceberg. There remain many unknown factors which require further research. In particular, the context of early life factors includes family environments and parental inferences as well as societal influences. With this in mind we selected the theme for this special issue.

There has been an excellent response, with various research ideas and approaches and the authors' making important contributions to this special issue. We wish to highly commend the authors for their well written papers exploring a range of issues related to early life factors associated with childhood obesity, which include epidemiological investigation, laboratory research, and intervention studies at various life-stages such as gestation period, infants, childcare, primary, and adolescents.

J. A. W. Baidal et al. examined underlying reasons for early life obesity risk factors and identify potential early life intervention strategies by conducting 7 focus groups with 49 Hispanic women who were pregnant or had children of age < 24 months. They concluded opportunities exist in the first 1000 days to improve Hispanic mothers' understanding of the role of early life weight gain in childhood obesity and other obesity risk factors. K. N. Dancause et al. assessed degree of objective hardship and subjective distress in women pregnant during severe flooding. Their results support the hypothesis that prenatal stress increases adiposity beginning in childhood and suggest that early gestation is a sensitive period.

Adolescence is a much neglected focus for overweight and obesity research. K. J. Sawka et al. address this gap by using social network analysis to examine how friendships affect sedentary behaviour and physical activity levels. Examining a cross-sectional analysis of 1061 adolescents (11–15 years), they found that adolescents with no friendship nominations participated in less moderate-vigorous physical activity (MVPA). A. L. Rodríguez-Ventura et al. also explored the barriers to losing weight experienced by children and adolescents in Mexico from the perspective of the children/adolescents and their parents using a series of focus groups. They found that barriers to losing weight included a perception that they were not overweight and not recognising overweight or obesity as a disease with serious consequences.

Very early overweight prevention programs can begin during pregnancy, with a focus on healthy weight gain by the mother. E. Y. Lau et al. conducted a systematic review of the literature on the association between gestational weight gain (GWG) and offspring's body weight with a focus on prospective and retrospective cohort studies. The authors found that total GWG and exceeding the recommendation were associated with higher BMI z-score and elevated risk of overweight or obesity in offspring.

Acknowledging that parents play a critical role in developing and shaping their children's physical activity and sedentary behaviours, particularly in the early years of life, H. Xu et al. also conducted a systematic review of associations of parental influences with physical activity and screen time among young children. Their findings suggest that parents' encouragement and support can increase children's physical activity, and reducing parents' own screen time can lead to decreased child screen time.

A. D. Keita et al. report on the feasibility and acceptability of a new early intervention program, the Healthy Homes, Healthy Families Pilot Study, which builds on the success of the home-based Healthy Beginnings program [4]. The Healthy Homes, Healthy Families Pilot Study, was designed to empower low-income racially/ethnically diverse parents to modify their children's health behaviours. They found vegetable intake among children significantly increased at follow-up, and fruit juice consumption decreased. J. Bonnet et al. also focused on early intervention and the idea of introducing discussion with parents of children's healthy weight when the child is 12 months old. They identified that children at this age were already demonstrating poor nutrition and physical activity behaviours and proposed that talking with parents at the 12-month visit with the family medicine primary care providers about "French fries" and nutrition was potentially an important opportunity for health promotion.

Using theory is important in developing and evaluating programs, and R. Lakshman et al. used the Medical Research Council framework for the development and evaluation of complex interventions: the baby milk intervention and trial. They reviewed the epidemiological evidence on early life risk factors for obesity and interventions to prevent obesity in this age group and identified the prevention of excess weight gain in bottle-fed babies and appropriate weaning as intervention targets. They developed intervention materials and evaluation tools and conducted qualitative studies with mothers (intervention recipients) and healthcare professionals (intervention deliverers) to refine them. Evaluation will follow, but it was noted that the rigorous development process was resource intensive.

A. C. Lindsay et al. described how childcare providers play an influential role in promoting healthful eating and physical activity behaviors of preschool children in their care. They also identified many barriers and challenges in establishing and maintaining healthful nutrition and physical activity behaviors, including high cost of healthy foods, cold weather, and physical environment of childcare centers and homes. K. Röttger et al. also sought to explore physical activity in the preschool setting, as this can be a time when gross motor skills are developed. Using direct accelerometry and anthropometrical and family-related data, they compared physical activity levels of 114 children attending different preschool settings in four cities of the trinational Upper Rhine region (Freiburg, Landau/Germany, Basel/Switzerland, and Strasbourg/France). Children from Strasbourg and Landau were significantly more passive than children from Basel and Freiburg, with the authors concluding that more open preschool systems such as those in Basel, Freiburg, and Landau did not lead to more physical activity "per se" compared to the highly regimented desk-based system in France.

School based programs continue to be important, and S. Kobel et al. report on the results of primary school focused program "Join the Healthy Boat." This teacher delivered program focused on increasing physical activity, decreasing screen media use, more regular breakfast, and reducing the consumption of soft drinks. 1943 primary school children participated in the cluster-randomised study. Significant effects were found in the intervention group for screen media use among girls, for nonmigrant children, and children with parents having a low education level.

While recognising overweight and obesity as significant public health problems, S. N. Saeidlou et al. sought to examine the more traditional developing country problem of malnutrition. Working with the Office of Community Nutrition Improvement and the United Nations Children's Fund, they conducted a prevalence study of malnutrition and obesity in 902 children under 5 years old in the Salmas district of North West Azerbaijan, Iran, in 2011. The prevalence of obesity and overweight in children was 1.3% and 5.1%, respectively. They found that the prevalence of malnutrition based on underweight, stunting, and wasting was estimated to be 2.3%, 7.3%, and 1.4% among children, respectively, and was more common in rural areas.

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Research Article

Calorie Labeling in a Rural Middle School Influences Food Selection: Findings from Community-Based Participatory Research

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Background. Calorie labeling at the point-of-purchase in chain restaurants has been shown to reduce energy intake. *Objective.* To investigate the impact of point-of-purchase calorie information at one rural middle school. *Methods.* With a community-based participatory research framework a mixed method approach was used to evaluate the impact of point-of-purchase calorie information. Students in grades 6–8, dining at the school cafeteria January and February 2010, participated for 17 school days each month; in January a menu was offered in the usual manner without calorie labels; the same menu was prepared in February with the addition of calorie labels at point-of-purchase. Gross calories served per student were measured each day allowing for matched comparison by menu. In March/April of 2010, 32 students who ate in the cafeteria 3 or more times per week were interviewed regarding their views on menu labeling. *Results.* Calorie consumption decreased by an average of 47 calories/day; fat intake reduced by 2.1 grams/day. Five main themes were consistent throughout the interviews. *Conclusion.* Point-of-purchase calorie labels can play a role in reducing the number of calories consumed by middle school age children at the lunch. The majority of students interviewed found the calorie labels helped them choose healthier food.

1. Introduction

Escalating rates of obesity may cause the current generation of children to have a life expectancy shorter than that of their parents [1]. Overweight and obese adolescents are now presenting with type 2 diabetes, dyslipidemia, and hypertension, diseases not previously seen in this age group [2, 3]. Swift action is needed to reverse these trends.

Schools are in a unique position to influence the diets of children and adolescents. Most students attend school for six or more hours per day, 180 days per year [4]. The majority of students consume a school lunch and some may also have a school breakfast, allowing over 47% of their total daily energy intake to be obtained in the school setting [5].

Menu labeling in chain and fast-food restaurants has received increasing attention as a policy to reduce energy intake. Findings show patrons making healthier, lower calorie food choices when calorie information is available [6, 7]. Encouraging findings at the local and state level have led to national legislation requiring menu labeling [8, 9]. Despite these positive results, a paucity of research exists on both the effect of menu labeling or calorie labeling in the school setting and on adolescents' opinions of labeling measures.

Jefferson County Middle School (JCMS) provides the ideal setting to examine the impact of menu labeling in schools. It is a public school situated in a low income area with just over 79% of its students entitled to free or reduced price cafeteria lunches and 64.6% of students are members of an ethnic minority. Although obesity is a national and international public health concern, research suggests that children and adolescents who live in multiethnic, low-income neighborhoods are at particularly high risk for obesity [10]. Adolescent obesity is a considerable problem at JCMS where 32.5% of sixth and eighth grade students were found to have a BMI above the 95th percentile, placing them in the obese category. Therefore, the Mountain View Community Health Improvement and Research Partnership, a community-based participatory research (CBPR) partnership, selected this school-based approach as one method aimed at the prevention of overweight.

To our knowledge only one other study has evaluated the impact of menu labeling in schools with college freshman and the results showed a positive impact [11]. We hypothesized calorie information at the point-of-purchase would influence students' food choices. The aim of the study was to investigate the impact of calorie posting at the point-of-purchase in a middle school cafeteria.

2. Methods

This study employed a mixed-method design including both qualitative and quantitative data collection. Ethical approval for the study was obtained by the Oregon Health and Science University and the North West Indian Health Region. The formation of the Mountain View Community Health Improvement and Research Partnership has been described in detail previously [12]. In brief, this partnership includes a wide range of stakeholders with a common goal of improving community health.

2.1. Subject Recruitment and Setting. The study was carried out in the Jefferson County Middle School (JCMS), Madras, Oregon, United States. The school is situated in a low-income community and participates in the United States Department of Agriculture (USDA) National School Lunch Program. Students included males and females aged 11 to 15 years of age in 6th–8th grade. On average, seventy-eight percent (daily average $N = 531$) of JCMS students participated in the school lunch program over the two-month study period and were included in the analysis of gross calories purchased per student. In January 2010 the cafeteria menu was presented as "usual" without calorie labels. In February 2010 the identical menu was presented with calorie labels at the point-of-purchase. Calorie labels were printed, laminated, and placed above the corresponding items on the sneeze guard for both the hot and cold food lines. Gross calorie consumption was calculated by weighing each food and beverage option before service and after service, imputing weights into a USDA approved nutrient database (Nutrikids), and dividing by the total number of children served per day. Gross calorie consumption assesses changes in total calories on a group level rather than on an individual level. Faculty and staff were excluded and used a separate salad bar for the duration of the study to uphold the accuracy of the weights. During the study period, after school sport offerings remain identical, girls can choose to play basketball and boys wrestling.

To recruit participants for the qualitative interviews, a letter of invitation was sent to students that ate lunch three or more times per week in all three grades. Consent for the parents and assent for the minor age participants were included along with a postage paid return envelope. Students also had the option to directly return the forms to the lunch room leader who was part of the CBPR partnership. To encourage participation, a gift card valued at $10.00 for either a local grocery store or subway sandwich shop was offered to the students. All interviews were conducted at JCMS during the school day.

Interviews followed a guided approach to ensure that the same general areas were discussed with each interviewee [13]. Interviews were audiotaped, transcribed verbatim, and analyzed for key themes by three researchers. First the transcripts were reviewed to achieve familiarity with the data. Key statements were coded deductively with codes conforming to interview guide questions. Next, the transcripts were reread to inductively identify areas not detected with the "top down" method of analysis and then recoded to incorporate the emergent codes [13]. Each code was reviewed and the five most relevant themes were identified.

2.2. Statistical Analysis. Statistical analysis was done using SAS 9.2. Consumption of menu items prepared on site was estimated by the difference between starting and ending weights; the nutrient composition of these items was estimated from the item recipes. Consumption of prepackaged items (e.g., milk, commercial salads) was estimated by the difference in units; nutrient composition for these items was estimated by the item labels. Per student fat and calorie and fat consumptions were computed and paired by menu matching. Pre- and postlabeling per student consumption of kilocalories fat and was analyzed using paired t-tests.

3. Results

As summarized in Table 1, the presence of calorie labels resulted in a mean decrease of 47 calories per student (95% CI $= -77$ to -18, $P = 0.0040$) and 2.1 grams of total fat per student (95% CI $= -3.3$ to -0.9, $P = 0.0025$).

After assessment of gross caloric changes, 32 students were interviewed. A summary of participants is shown in Table 2.

Following these 32 interviews, the qualitative analysis produced five significant themes. For each theme, the main points are presented along with relevant quotations (Table 3).

3.1. Obesity Epidemic and School Responsibility. Many students were aware of the adolescent obesity epidemic. One interviewee stated "kids are getting bigger and heavier nowadays than they used to be." The students believed it was the schools responsibility to help stop this trend and aid the students in achieving a healthy weight. Many students were also eager to express their specific ideas how school could make the suggested changes. For example, students suggested announcing the healthier cafeteria options every morning to make choosing healthy food easier.

Table 1: Changes in calorie and fat consumption.

Meal	Kcal consumed Per student		Grams fat consumed per student	
	Prelabel	Postlabel	Prelabel	Postlabel
1	740	766	26.0	27.2
2	725	602	28.3	23.5
3	596	576	16.3	16.2
4	807	748	34.0	30.9
6	819	672	24.6	20.8
7	669	662	27.6	26.9
8	570	545	17.1	16.2
9	430	441	11.7	13.1
10	745	767	27.9	28.5
11	711	617	23.5	20.0
12	617	579	19.7	17.0
13	773	745	33.4	31.4
14	689	641	25.1	22.5
15	559	467	17.8	13.4
16	868	737	23.6	17.2
17	366	363	13.4	12.1
Average	**668 ± 138**	**621 ± 122**	**23.1 ± 6.6**	**21.1 ± 6.4**
	Kcal/student Mean difference = −47 Std. Dev of difference = 14 95% CI = −77 to −18 $P = 0.0040$		Total Fat g/student Mean difference = −2.1 Std. Dev of difference = 0.6 95% CI = −3.3 to −0.9 $P = 0.0025$	

Table 2: Sex and grade of students participating in menu labeling interviews ($n = 32$).

	Males	Females	Total
Sixth grade	6	6	12
Seventh grade	4	7	11
Eighth grade	5	4	9
Total	**15**	**17**	**32**

3.2. Nutritional Knowledge Was Related to Home Environment. Students were asked the extent to which their families discussed nutrition and used nutrition labels. Students' responses suggest that their knowledge of healthy eating is highly dependent on the nutrition practices of their parents and siblings. They tended to mimic the behavior of their family members when it came to reading labels stating "My mom, my sisters, and me, we look at the nutrition labels." A lack of importance placed on nutrition in the home seemed to reinforce students' negative attitudes towards healthy eating and act as a further deterrent to menu label usage. Some parents had attempted to scare their children into consuming less. "My mom tries to scare me about calories; that way I won't have as much in a day." However, these strategies often resulted in students having inaccurate nutrition knowledge. Overall, it was mainly students whose parents demonstrated an interest in nutrition that were positive about seeking nutritional information.

3.3. Taste Drives Intake. Most participants agreed that nutrition and being a healthy weight were important to them but taste was declared the most important factor. The appearance and nutritional content of food also rated highly. One student remarked that the only time he did not use the calorie labels to make a lower calorie choice was a when a certain food "looked really good." Although many students considered nutrition information to be important, and widespread poor nutritional knowledge was evident. Very few students could correctly identify their energy requirements or understand the role of calories in achieving energy balance: "They're {calories} something that builds up inside your intestine." This is despite studying nutrition in the mandatory health class.

3.4. Calorie Labels and Health. Most students considered displaying the calorie amounts to be important and one student expressed a desire for restaurants to also have the calorie counts on display. Although many of the interviewees had an awareness of the connection between obesity and chronic disease, a small number believed maintaining a healthy weight was primarily associated with image. When asked was nutrition information important to maintain a healthy weight, one student replied that he did not "judge people by their looks." Furthermore, some students admitted having no interest in nutrition "I saw the calories but I didn't use them."

Table 3: Five significant themes.

Themes	Quotations
Theme 1: Students want nutrition information and felt it was a school's duty to help them achieve and maintain a healthy weight.	
Students want schools to provide nutrition information to help them make healthier food choices and achieve a healthy weight. Students wanted the school to (i) provide the calorie labels at point of purchase, (ii) provide more opportunities for activity, (iii) discuss nutrition more in the classroom (iv) only give healthy choices at lunch, (v) announce what the healthy cafeteria options are everyday	"They 're {labels} good and I think they should start showing them more often" "I think they should put those little signs back up" More "variety of fruit and vegetables" "selections of healthy food", "food with less fat" and "with lower calories" "Give extra time at recess. Cause they talked about an hour of exercise that you need every day in health class" "offer sweet things less frequently"
Students recognized that the school was trying to take measures to combat obesity.	"with labels they're {school}, at least, attempting to do something about it" "My teacher mentioned the labels once and that's when I went looking for them"
Many students want classroom based nutritional education alongside menu labeling in the cafeteria.	"I think they should have an assembly and talk to everybody about labels"
Theme 2: Student understanding of nutrition and use of nutritional information were related to home environment.	
Students with parents who discussed nutrition at home and used nutritional labels were more likely to (i) notice and use the lunchroom labels, (ii) use nutritional labels on prepackaged food, (iii) have a greater overall awareness about nutrition and healthy eating, (iv) place greater importance on nutrition in general	"Sometimes my dad just tells me we gotta eat healthy" "she {mother} likes it when things have labels so that she can make a choice" "I'd go home and talk to my parents and tell them what we had at school and we would talk about it" "We look up to see how much sugar it has for fun. We just start guessing, then someone gets it right" "My mom, my sisters and me. We look at the nutrition label thing"
Students who did not discuss nutrition at home (i) had poor nutritional knowledge, (ii) were less likely to use the calorie labels, (iii) were to assess the schools obesity problem	Q. "how is it that you make decisions about what you're gonna eat?" A. "My dad, he usually just says he eats what he wants" "We just, kind of, eat whatever there is" "We don't talk about nutrition" Q. "Do you think there's a lot or a little problem with overweight at the school?". . . A. "Not that much."
Some students used their knowledge of the school calorie labels back in their home.	"I use it, like, when I prepare some foods at home"
Theme 3: Taste preference, nutrition, and being a healthy weight are important to most of the students.	
Taste, nutrition, and appearance are the most important factors for students when choosing food. Taste was the most significant factor for students Nutritious food needs to taste and look good in order for the students to eat it. Some students highly prioritized taste over nutritional content of food	"Taste and portion size and to see how healthy it is for me. Those are the 3 most important things." "If it don't taste and look good, I'm not gonna eat it" "I don't really care how high the calories are as long as it tastes good"
Theme 4: Most but not all students admitted to noticing and using the calorie labels to make healthier food choices.	
The students who claimed to use the labels all used them to make healthier lower calorie food choices. Reasons given for menu labeling use include (i) helping to make lower calorie food choices, (ii) helping when comparing the calorie content of food, (iii) being easier to make healthier food choices, (iv) giving an idea of calories consumed at lunch each day, (v) helping when choosing smaller potions, (vi) reminding them to think of nutrition when choosing a food	"now I get something that doesn't have as much calories" "I didn't get the stuff I used to get. . .I ate more fruit" "I tried to grab low calorie, healthy foods and not grab junk food" "I had a piece of paper with me the second day to see how many calories I had during lunch" "I took a smaller plate of chips" "helped me choose the right food to eat" "It helps you think about nutrition"
Theme 5: The calorie labels and nutritionally related topics in general were not discussed among students.	
Most students did not discuss the presence of the labels in the cafeteria with their peers. Initial interest shown by students prompted some discussion.	"I have never heard a classmate of mine say anything" "At first everyone said what's up with the food calories" "We did talk about it for a little bit, but then we would just focus on the food"

Some students stated the calorie labels “helped {them} make healthier choices.” A positive side effect was that by choosing lower calorie items many students automatically chose lower fat foods “I switched from a side of chips to salad.” Many students were surprised by the high number of calories in some foods which lead them to choosing a lower calorie alternative “I was surprised how high the calories were so I took less.” In some cases the adolescents found that the labels did not impact the specific food they ate but the quantity, with many opting for smaller portions.

3.5. Not Hall Talk. When it came to the labels themselves, the color, font, size, and positioning of the labels were the main areas highlighted by the interviewees. As one student remarked “nobody would really have time just to stop right there and look at it because you have to keep on going.” Another student mentioned that “when we see it big, we want to know what that is, because you notice it more.” Students who did not use the labels did not mind their presence. “Some of my friends thought it was cool to have them and some of them didn’t really care.” Overall, most students revealed that they would like to see the calorie information displayed but that it is only useful “if people actually read it, if they don’t it’s a waste of time.” However, most of the students interviewed stated they did not discuss the calorie labels with their friends.

4. Discussion

This mixed-method study examined both the change in gross calories consumed and students’ opinions. Quantitative results demonstrated that calorie labels at the point-of-purchase decreased caloric consumption. Although some students claimed not to notice and/or use the calorie information during the interviews, they may simply be unaware of the impact calorie labels had on their selection of food or it may be due to reluctance among some students to admit to using the calorie labels. The later reason may be a more plausible explanation as the majority of interviewees also claimed not to have discussed nutrition in general with their peers.

Students in this study believed the school is responsible for helping them achieve and maintain a healthy weight. Students wanted healthier cafeteria choices along with nutrition information to guide their food decisions and facilitate healthier eating. To demonstrate their interest, students identified a number of potential healthy eating initiatives including providing “a better variety of fruit and vegetables,” “more selections of healthy food,” “food with less fat,” and “with lower calories.”

Students also recognized that by introducing menu labels the school was trying to take measures to combat obesity, “with labels they are {school} at least attempting to do something about it.” Further, this study demonstrated that students whose parents discussed nutrition at home and used nutritional labels were more likely to (1) notice and use the calorie labels, (2) use nutritional labels on prepackaged food, (3) have a greater overall awareness about nutrition and healthy eating, and (4) place a greater importance on nutrition in general. The third theme indicated that students chose products from the cafeteria based on taste, nutrition, and food appearance. Menu labeling is an intervention for which efficacy depends on other factors, such as the simultaneous availability of attractive, highly palatable items [14]. External cues and emotional and physiological drivers often override rational thought when it comes to food consumption. This is consistent with the findings of previous studies [15]. However, fruit and vegetables were also highly regarded. The results indicate a need to increase concern about nutrition, as factors such as taste and appearance still appear to be more important considerations for most students.

The majority of the students interviewed believed the availability of calorie information enabled them to make healthier, more informed purchase decisions and “not grab junk food.” The positive feedback given by the interviewees corresponds with the significant decrease in gross calories and fat purchased per student recorded when calorie labels were present. The students believed the information helped them to estimate the calories they consumed at lunch and to choose smaller portion sizes. This finding is consistent with research by Girz et al. [16], who noted a decrease in portion size amongst a sample of adults when menu labels were introduced. These findings demonstrate that modifying the school environment by introducing point-of-purchase calorie labels led to a positive behavior change in students. In the current study, interviewed adolescents appeared to have a lack of awareness or to have forgotten about the importance of calorie content of food. The success of the calorie labeling may be attributed to the labels presenting a daily reminder of this information. The decrease in calories observed in this study may be partly attributed to the nutrition education that is integrated into the school curriculum. A recent meta-analysis found that when calorie labels were provided along with contextual or interpretive nutritional information, consumers selected fewer calories [17]. Interestingly, despite the decrease in gross calories purchased by students when calorie labels were present, most interviewees did not admit to discussing the labels with their peers. It has been identified in the literature that students think it is important for social reasons not to be overweight and can struggle with the pressure to be a socially desirable body weight [18]. It could be hypothesized there is some stigma attached to discussing nutritionally related topics as one student exclaimed: “we don’t talk about that kind of stuff.” However, the support of friends for healthy eating has been positively associated with an increase in vegetable consumption [19]. Our results indicate there are barriers when it comes to adolescents discussing nutrition with their peers. The school should encourage conversation in the area of healthy eating and nutrition to rid any stigma these topics may attract.

4.1. Strengths and Limitations of the Study. The present study has a number of strengths. The majority of studies previously conducted have examined the effects of calorie posting in fast-food or chain-style restaurants but school cafeterias have largely been neglected. The current study contributes to the limited research in this area as we analyzed the impact of calorie labeling on a school cafeteria and the students reactions to these labels. The study also measured adolescents' gross consumption rather than their behavioral intent. Consequently, social desirability bias in reporting is of less concern and internal validity is probably better than studies that only measured behavioral intent [20–22]. Participants were also exposed to the calorie information for a long period of time (17 days) in a familiar setting, whereas simulation studies of intended or hypothetical food choices fail to incorporate the social nature of food choices. The study also included both sexes, although these were not examined separately.

Weight gain can occur over time from relatively small differences between the number of calories consumed and calories expended (e.g., 50 to 100 calories per day) [4]. Conversely, calorie reductions as small as those seen in the present study may be enough to lead to sustained weight loss over time and may be more realistic than dramatic changes.

The study also has several limitations. First, the results only demonstrate the positive short-term benefits of calorie labeling and it is not possible to conclude that these results will be stable for long term due to a lack of follow-up study. Second, only one middle school, in one school district, was examined so it is unclear how demographic variables may influence responses to calorie information in other settings. Furthermore, previous studies have demonstrated that adult males tend to choose higher calorie meals than adult females. The current study design did not allow for separation by sex and therefore, we cannot ascertain if the findings were strongly influenced by just one sex [23]. Third, it was not possible to explore whether the effects of calorie information will lead to long-term weight loss or weight maintenance in the adolescent population. Moreover, our findings could have been influenced by external factors such as weather differences or physical activity expenditure differences but as we conducted our study over the winter period on the same number of contact days we have minimized this influence to the extent possible. It is also possible that children consumed fewer calories at school during the intervention but compensated for these calories later in the day; we have not measured this aspect. We also acknowledge that we assessed gross calories based on food selection rather than food intake and therefore we can only state that children selected fewer calories. These findings provide preliminary insight into middle school student behavior. Additional research in different settings with different age groups is warranted. For example, Yamamoto et al. [20] demonstrated that calorie information influenced reported purchase intentions at some food outlets but not others. These results suggest that our findings may apply to some school settings but not all. In any case the current study contributes to the limited literature available in the area of calorie labeling in school settings.

5. Conclusions

No single solution will reverse the adolescent obesity epidemic. Calorie labels in schools are no exception but they may be part of the solution. As part of a broader movement, calorie labeling may induce systemic effects that over time could initiate a virtuous cycle. For instance, publishing caloric data at the point-of-purchase in schools could increase awareness and change student purchasing decisions outside of the school setting, leading to fewer calories consumed. The results of this CBPR study are encouraging and indicate that calorie labeling has a beneficial effect on student food choices. Calorie labels at the point-of-purchase are a promising approach to tackling the growing problem of adolescent obesity.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Authors' Contribution

Monica Hunsberger conceptualized the study and collected data with coauthors and community partners. Paul McGinnis, Beth Ann Beamer, and Jamie Smith assisted in conceptualizing the study and collecting data and Jean O'Malley completed all statistical analyses. All authors worked on manuscript preparation and final edits.

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Research Article

Reducing Hispanic Children's Obesity Risk Factors in the First 1000 Days of Life: A Qualitative Analysis

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Objectives. Modifiable behaviors during the first 1000 days (conception age 24 months) mediate Hispanic children's obesity disparities. We aimed to examine underlying reasons for early life obesity risk factors and identify potential early life intervention strategies. *Methods*. We conducted 7 focus groups with 49 Hispanic women who were pregnant or had children < age 24 months. Domains included influences on childhood obesity risk factors and future intervention ideas. We analyzed data with immersion-crystallization methods until no new themes emerged. *Results*. Themes included coping with pregnancy may trump healthy eating and physical activity; early life weight gain is unrelated to later life obesity; fear of infant hunger drives bottle and early solids introduction; beliefs about infant taste promote early solids and sugary beverage introduction; and belief that screen time promotes infant development. Mothers identified physicians, nutritionists, and relatives as important health information sources and expressed interest in mobile technology and group or home visits for interventions. *Conclusion*. Opportunities exist in the first 1000 days to improve Hispanic mothers' understanding of the role of early life weight gain in childhood obesity and other obesity risk factors. Interventions that link health care and public health systems and include extended family may prevent obesity among Hispanic children.

1. Introduction

Emerging national data suggests a plateau in obesity prevalence among children in the USA [1]. Yet all age groups continue to have high obesity prevalence, with 16.9% US children aged 2–12 years affected by obesity [1]. Socioeconomic and racial/ethnic disparities in childhood obesity persist and appear to be widening [1–4]. Hispanic children of age 2–5 years have a fivefold higher prevalence of obesity compared to non-Hispanic white counterparts, suggesting that the etiologies of disparities in childhood obesity start early in life [5, 6].

The first 1000 days of life—conception through 24 months of age—are recognized as a critical period for optimal nutrition and development [7]. Racial/ethnic differences in modifiable risk factors for childhood obesity exist during pregnancy, infancy, and early childhood [8–12]. Among Hispanic children, nonexclusive breastfeeding, early introduction of solid foods, sugar-sweetened beverage intake, screen time, insufficient sleep, and other modifiable behaviors during infancy and early childhood contribute substantially to racial/ethnic disparities in mid-childhood obesity [13]. The underlying reasons for these racial/ethnic differences in early life risk factors are unknown. In order to reduce racial/ethnic

Table 1: Focus group discussion guide domains according to focus group type.

Domain	Pregnancy groups	Infancy groups	Early childhood groups
Health information sources	√	√	√
Beliefs about weight gain during respective life course period	√	√	√
Beliefs about and influences on formation of obesity risk factors			
(i) Infant/child bottle use and breastfeeding	√	√	√
(ii) Introduction of solid foods to infant/child		√	√
(iii) Infant/child ability to self-regulate feeding		√	√
(iv) Infant/child sleep		√	√
(v) Infant/child screen time		√	√
(vi) Sugar-sweetened beverage intake and diet quality during respective life course period	√	√	√
(vii) Physical activity during pregnancy	√		
Parental explanatory factors for childhood obesity	√	√	√
Prospective future interventions to reduce childhood obesity	√	√	√

disparities in childhood obesity, root origins of obesity risk factors and unique approaches to prevent obesity in Hispanic children during the first 1000 days of life must be identified.

The overall goals of this qualitative study were to examine the underlying reasons for early life obesity risk factors during pregnancy, infancy, and early childhood among Hispanic families and to identify intervention strategies that have the potential to reduce obesity risk factors early in life. Qualitative methods are uniquely suited to reveal beliefs that lead to different behaviors in minority populations, and focus group discussions allow for observation of psychosocial dynamics that would not be identified in interviews. We aimed to identify beliefs and perceptions of pregnancy health; perceptions of and influences on infant and child weight gain, diet, screen time, and insufficient sleep; maternal explanatory factors for childhood obesity; and potentially effective future obesity prevention intervention approaches among Hispanic families.

2. Methods

2.1. Study Setting and Participants. We conducted a total of 7 semistructured focus group discussions with Hispanic mothers at three life stages: 2 groups of women during pregnancy, 3 groups of mothers of infants (birth to age <7 months), and 2 groups of mothers of children in early childhood (age 7 months to 24 months). Women with a prenatal visit for a singleton gestation were eligible for pregnancy groups. Parents (mothers or fathers) of children between birth and age 6.9 months were eligible for enrollment in infancy groups, and those with children of age 7 through 24 months were eligible for early childhood groups. Pregnant women and parents of infants and children under 2 years of age who could respond to questions in English or Spanish were eligible for recruitment. We excluded families for whom (1) the pregnant woman or eligible caretaker was under 18 years of age, (2) the pregnant woman or child had chronic medical conditions that interfered with growth, nutrition, or physical activity, or (3) the health care provider thought study participation was inappropriate.

Research staff recruited patients who had an outpatient visit for routine prenatal or pediatric care at a federally qualified community health center (CHC) with a multispecialty provider group in eastern Massachusetts that serves a racial/ethnically and socioeconomically diverse population. A total of 96 eligible parents were recruited for focus groups, among which 18 were ineligible, 29 declined to participate (16 uninterested, 8 unavailable at time of focus group, 3 unable to find child care, and 2 unable to obtain transportation), and 49 elected to participate. We provided $40 for participation and $20 to reimburse for childcare and travel.

2.2. Data Collection. The research team developed a focus group discussion guide over multiple meetings. Table 1 shows discussion guide domains which included (1) perceptions of weight gain during respective life stage; (2) explanatory factors for development of childhood obesity; (3) beliefs about obesity risk factors; and (4) perceptions of potential future interventions.

We conducted all focus groups at the CHC between July 2013 and January 2014. We set an initial target of 6 focus group discussions (2 for each life course stage), but we added a third infancy group for consistency in sample size across life course stages. At recruitment, each participant completed a brief survey asking general demographic questions such as age, educational attainment, and number of children in household. For each focus group, a professional bilingual moderator, whose race/ethnicity was concordant with the participants', facilitated the discussions to enhance the comfort level of participants. The same moderator conducted all focus groups. The moderator was trained on study aims and discussion guide questions through a half-day session and recurrent study team phone calls. The focus groups were primarily in Spanish with some English interpretation. Bilingual study staff members took notes during discussions, and team members debriefed after each focus group. Discussions were

Table 2: Mother and child characteristics according to focus group discussion participation. Data from 49 Hispanic mothers.

	Pregnancy groups (N = 17)	Infancy groups (N = 15)	Early childhood groups (N = 17)
Parent/family characteristic			
Maternal age, years, and mean (SD)	25.6 (6.4)	25.6 (7.5)	27.9 (6.1)
Education, high school graduate, n (%)	13 (76%)	9 (60%)	12 (71%)
Nulliparous, n (%)	14 (82%)	10 (67%)	6 (35%)
Married/cohabiting, n (%)	11 (65%)	9 (60%)	10 (59%)
US-born, n (%)	6 (35%)	7 (47%)	6 (35%)
Language comfort			
Spanish-only	9 (53%)	4 (27%)	3 (18%)
Either English or Spanish	8 (47%)	11 (73%)	13 (76%)
Gestational age (months)	5.1 (1.8)	n/a	n/a
Child characteristics			
Age (months)	n/a	2.8 (2.0)	14.3 (5.3)

audio-recorded and transcribed verbatim in Spanish, and then professionally translated to English. Participants were assigned random numbers to replace identifying information and protect confidentiality. The institutional review board at Massachusetts General Hospital *for* Children approved the study protocols. All participants provided informed, written consent prior to participation.

2.3. Analytic Approach. We conducted content analysis of the transcribed focus group discussions using immersion-crystallization techniques [14]. Immersion-crystallization is an iterative analytic approach with two stages: immersion and crystallization. During the immersion process, researchers immerse themselves in the data collected by reading data in detail. During crystallization, researchers analyze the data examined during the immersion process for important patterns and themes. The immersion and crystallization processes are continued until no new patterns or themes emerge. Specifically, research team members (JWB, SC, CC, and REG) read the transcripts and discussed the data as a group repeatedly to determine topical content and emerging themes. Research team members took detailed notes during meetings. Following the immersion-crystallization processes, we developed and refined a codebook through iterative discussions. We used NVivo 10 software to import transcripts, code the data, and organize codes. Two members of the research team (SC and CC) coded one transcript and reviewed consistency of coding to ensure consensus on categorization of the data. One member of the team (SC) coded all remaining transcripts. We then used the code reports to continue content analysis and interpretation of themes [15]. We continued analysis until no new major themes emerged and we resolved discrepancies at research team meetings. The bilingual focus group moderator and study staff present at focus group discussions agreed with data interpretation.

3. Results

3.1. Participant Characteristics. Table 2 shows characteristics of the 49 mothers who participated. Mean maternal age was 26.4 (SD 6.6) years. Mean gestational age in pregnancy groups was 5.1 (SD 1.8) months. Mean child age was 2.8 (SD 2.0) months in infancy groups and 14.3 (5.3) months in early childhood groups. More than half of the women were born outside USA, and most spoke both Spanish and English.

3.2. Beliefs and Perceptions of Pregnancy Health. Table 3 shows themes related to pregnancy health.

Mothers Coping with Their Own Physical Changes during Pregnancy May Trump Healthy Eating and Physical Activity. Most women in all seven groups believed that the keys to a healthy pregnancy lie in healthy eating and physical activity. Many women in the pregnancy groups reported improving dietary habits during pregnancy by consuming a balanced diet of fruit, vegetables, dairy, and lean proteins, while avoiding fast food and soda. However, some reported that nausea made tolerating healthy foods difficult, saying "Most food hurts me, so I feel like my stomach is heavy. . .vegetables, that I know are good and I've always liked, they make me feel like vomiting" (Pregnancy Group). Instead cravings or nausea led to consumption of foods that they perceived as unhealthy (i.e., fried and salty foods and candy).

In all seven groups, most women noted that physical activity during pregnancy is important to improve comfort, reduce duration of labor, and enhance maternal energy and health. Many women reported lack of physical activity because they were tired, more easily fatigued, or felt uncomfortable with their pregnancy weight. One woman said, "I am not doing any physical activity because of laziness. Because before I was studying. I went back and forth on foot. And now that I'm done studying—and I say I'm not going to get out of bed" (Pregnancy Group). Although some women believed that physical activity during pregnancy could improve offspring's health, none linked it to prevention of excessive gestational weight gain or childhood obesity.

Weight Extremes Should Be Avoided during Pregnancy. Most women believed that it is possible to have excessive gestational weight gain, and some equated its health risks to those of insufficient weight gain. Perceived complications of excessive gestational weight gain included difficult labor, need for cesarean section, and maternal health complications.

Table 3: Themes related to weight gain and obesity risk factors in pregnancy, infancy, and early childhood among Hispanic women. ($n = 49$).

Beliefs and perceptions of pregnancy health
(i) Coping with own physical changes during pregnancy may trump healthy eating and physical activity
(ii) Weight extremes should be avoided during pregnancy
Perceptions of and influences on infant and child weight gain, feeding, screen time, and sleep
(i) Excess child weight gain in first years of life is possible but inconsequential
(ii) Maternal fear of infant hunger drives nonexclusive breastfeeding and addition of solid foods to bottles
(iii) Mothers feel responsible for ensuring infant satiety
(iv) Family beliefs about infant taste promote early introduction of solid foods and sugar-sweetened beverage intake
(v) Variation in maternal knowledge about healthy beverage choices for children
(vi) Maternal belief that screen time in the first two years of life is important for child development
(vii) Sleep routines should start in early life
Maternal explanatory factors for childhood obesity
(i) Maternal belief that early life weight gain impacts health but is unrelated to later life obesity
(ii) Overfeeding and early introduction of "adult" foods lead to childhood obesity

None identified maternal weight status or gestational weight gain as a risk factor for childhood obesity. All women had heard the popular expression that "pregnant women are eating for two" and none agreed with it. Several thought it was important to eat a variety of healthy foods to provide the right nutrients to their baby, rather than to gain enough weight for two people. One woman stated, "It's not eating for two, but knowing how to eat, for the baby you're carrying" (Pregnancy Group).

3.3. Perceptions of and Influences on Infant and Child Weight Gain, Feeding, Screen Time, and Sleep. Table 3 includes themes related to infant and child weight gain, feeding, screen time, and sleep.

Excess Child Weight Gain in First Years of Life Is Possible but Inconsequential. In infancy and early childhood groups, almost all mothers believed that infants and children under age 2 years could gain too much weight. When asked, several mothers disagreed with the popular saying "a chubby baby is a healthy baby." A few mothers in the infancy and early childhood groups did worry about their infant or child's risk for obesity and discussed their desire to prevent their infant from becoming obese. However, most mothers believed that excess weight in this age group, while possible, was not a problem unless specifically told otherwise by their pediatrician, stating that "you feed them what they want, and later when they start getting older they'll start knocking off some of the pounds" (Infancy Group).

Many mothers in infancy and early childhood groups had discussed their child's weight with a pediatrician and reviewed their child's growth charts. Most mothers reported that pediatricians are a trusted source of information on child weight gain. However, a few mothers had been told that their child was obese and did not believe the pediatrician. They either cited their own instincts as a mother as better than the doctor's medical knowledge or their own belief that there are not consequences to excess weight early in childhood.

Maternal Fear of Infant Hunger Drives Nonexclusive Breastfeeding and Addition of Solid Foods to Bottles. Although mothers in pregnancy, infancy, and early childhood groups identified exclusive breastfeeding as the best option for feeding their newborn, some mothers in infancy groups feared that breastfeeding did not provide sufficient nutrition for their baby. Several women reported concerns that inadequate breast milk production left their infant hungry, and a few women pumped to check the volume of breast milk produced. According to one mother, "I feel like I'm not giving her enough. . .because I do not see the amount coming out. . .when you do formula, you know how much you're giving. . .so I started pumping to see how much I could pump" (Infancy Group). Fear regarding inadequate breast milk volume led to supplemental or exclusive bottle feedings by some mothers.

Despite most mothers recognizing that solid foods should be introduced at or around 4–6 months of age, solids in the form of cereal, purees, or sugar added to bottles appeared to be an exception to this rule. "I've given my son, at three months old, rice cereal in his formula. There's nothing wrong with it in my opinion because the rice cereal has iron, it has protein, it has vitamins. . .And he sleeps more at night," according to one mother (Early Childhood Group). Mothers also reasoned that adding solids to bottles helped infants feel full, gain more weight, calm down, and receive adequate nutrition. Female family members were common sources of advice and example on feeding routines, including adding cereal and other solid foods to bottles.

Mothers Feel Responsible for Ensuring Infant Satiety. All mothers in all infancy and early childhood groups believed that they were attuned to their child's hunger and satiety cues. Several mothers believed that parents must feed their child under age 6 months until they were full. One mother explained, "I think that if he's younger than six months you have to [feed] him until you think [he's full] since they do not know, but from six months on, they—they know how much they want, and they make [it] known" (Early Childhood Group). Most mothers in infancy groups believed it was important for children to be full and cited satiety cues of losing interest in feeding, having a hard stomach, pushing the bottle away with hand or tongue, sighing, or falling asleep. Mothers in infancy groups commonly noted infant hunger cues of sucking/rooting, putting hand in mouth, and crying. In infancy groups, all mothers thought on-demand feeding was preferable. However, several still kept track of time between feeds, woke infants to feed, or fed infants while they were asleep.

Although most mothers in the early childhood groups showed confidence in their child's ability to express a desire for certain food or drink compared to when they were infants, they also noted that children might ask for food or drink for reasons other than hunger. "Sometimes kids want to keep eating and actually they do not need it. . .we mothers have to be very careful. . .because the baby can. . .gain weight that is not appropriate. . .that's what I always ask when I go to the nutritionist, is she OK for her age?" (Early Childhood Group). Mothers worried that eating in the absence of hunger could lead to childhood obesity, and they received advice from the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) nutritionists on portion sizes and balanced meals.

Family Beliefs about Infant Taste Development Promote Early Introduction of Solid Foods and Sugar-Sweetened Beverage Intake. Almost all mothers in infancy and early childhood groups described family beliefs that infants should experience a variety of foods to develop taste preferences, some starting as young as 1 month of age. Most reported that her child's grandmothers, aunts, fathers, and other male relatives "want to give her beans, rice, they want to give her food, on the contrary, not milk, food" (Infancy Group). Relatives fed young infants chocolate, fruits, lollipops, cookies, meats ground with beans or rice, and sports beverages. A few mothers gave their young children sports drinks or sodas because they perceived that after 1 year of age it is important to teach children to "taste." One mother explained, "I give her juice, and she's also tried soda. They have to try everything. . .so she (learns) the taste of everything" (Early Childhood Group). While a few mothers and reportedly many extended family members believed "tastes" of these foods would teach the child to eat or not eat certain foods, others, mainly male relatives, reportedly had a desire to provide larger food portions to make the child stronger. Most mothers expressed frustration with these practices, and several worried they could lead to development of illness, such as diarrhea. Most mothers did not feel empowered to change their relative's behaviors, but many did try to discuss their concerns with family members.

Variation in Maternal Knowledge about Healthy Beverage Choices for Children. Mothers stressed a preference for providing homemade or 100% juice as "natural" beverage options for children. "Well if it's 100 percent they are [healthy]. . . I make him his juice from the fruit itself, natural" (Early Childhood Group). Several reported diluting juice with water based on advice from pediatricians or WIC providers. Many mothers did not give their children soda, and a few participants discussed reading labels to avoid giving children beverages with added sugar. However, several mothers in early childhood groups did not distinguish between fruit drinks, sports drinks, and punch. Notably, one mother perceived that, unlike juice, sports drinks did not make her child hyperactive, stating "I give him more [sports drinks] than juice. . .because [sports drinks] contains minerals that the body needs. . ., and he does not get active or very hyperactive like [with] juices." Some mothers worried that giving juice or sugar-sweetened beverages to their child could make them hyperactive, but none spoke about concerns for sugar-containing beverages leading to obesity or other adverse health outcomes.

Maternal Belief That Screen Time in the First Two Years of Life Is Important for Child Development. All mothers in all infant and early childhood groups disagreed with the recommendation that children of age 2 years should not watch television, and some felt very strongly that television viewing was important for their child's visual and cognitive development. One mother stated, "It's good because she watches [learning videos] and then she learns more" (Infancy Group).

All mothers reported that their infants and young children watched television regularly, most for 1-2 hours daily. Some mothers reported that their infant or child routinely went to sleep while watching television, explaining "I have to put on the TV for her to fall asleep because she started watching television at three months and I would take her out and she cried, cried, cried" (Infancy Group). No mother reported being told by their pediatrician that their child should not watch television. Even if a pediatrician were to advise that their infant or child should not watch television, several mothers said they would seek additional information from other sources or would want evidence of a negative impact on child vision or cognitive development before they would reduce or eliminate their child's screen time. No mothers identified screen time as a risk factor for childhood obesity.

Sleep Routines Should Start in Early Life. In the infancy groups, mothers reported their children slept 10–16 hours, but all agreed that infants should sleep 14–16 hours over a 24-hour period. Most mothers in infancy groups thought sleep routines should start between 2–4 months of age, but several thought they should start after 6 months of age. In early childhood groups, mothers thought sleep routines should start at birth. Family members, the Internet, and television shows were cited by a few as sources of advice. "My grandfather would tell me that ever since he was born I should get him used to sleeping at night," according to one mother (Infancy). No one mentioned discussing child sleep routines with their pediatrician. In order to get their children to fall asleep, mothers changed positions, rocked them, gave them baths, snuggled with them, or gave them food or milk because they believed a full stomach would allow longer sleep. A few mothers thought that daytime physical activity was key to their child getting a good night's sleep. No mother recognized that curtailed sleep is a risk factor for childhood obesity.

3.4. Maternal Explanatory Factors for Childhood Obesity. Table 3 shows themes related to maternal explanatory factors for childhood obesity.

Maternal Belief That Early Life Weight Gain Impacts Health but Is Unrelated to Later Life Obesity. Many women in pregnancy groups believed that excessive gestational weight gain has negative impacts on infant health but did not include childhood obesity as a potential outcome. Many women discussed believing that maternal weight status and pregnancy weight gain do not contribute to childhood obesity and that child nutrition after birth was the most important contributor to childhood obesity. In infancy groups and early childhood groups, most mothers believed children could gain too much weight during the first 2 years of life.

In each life course period, most mothers did not identify early life weight gain as a risk factor for childhood obesity later in life. Mothers expressed a sense of hopelessness in being able to control future child weight status, and one said "I think the appetite could change... I'm assuming that it just depends on how you grow yourself... I think it's the baby. Not exactly what you're doing" (Infancy Group). Some women also demonstrated a lack of awareness that obesity could herald future diabetes risk, and a few women thought that diabetes could lead to obesity. One mother stated, "You cannot really control [development of childhood obesity]...if you have diabetes when you're pregnant, all kids are bound to be big, and then you have some [pregnant women] that eat a lot, and the babies come out five pounds, so it's like you cannot really control it" (Pregnancy Group). Several women strongly believed that the only explanation for overweight or obesity in young children would be a medical cause.

Overfeeding and Early Introduction of "Adult" Foods Lead to Childhood Obesity. In infancy and early childhood groups, mothers most commonly discussed feeding practices as the etiology of childhood obesity. Some mothers explained that overfeeding early in life could lead to a larger appetite or even an irreversible and potentially dangerous expansion of children's stomachs stating that "I know people who have damaged their stomachs giving them food, feeding them... giving them food that is not [right] for their bodies and they open the belly with, it gives them more extra room" (Infancy). Mothers cited an unhealthy diet as another cause for childhood obesity.

Several mothers also noted that family and cultural influences on introduction of table foods before 6 months of age could lead to excess weight gain. "Dominicans—I include myself—for excess weight—that they feed him too much at a very early age, so they encourage him to eat from the time [they're] small. Food—rice, beans, meat...way before [6 months of age]" (Early Childhood). However, many mothers disagreed with this idea and did not believe that early introduction of solid foods caused obesity.

3.5. Potential Effective Childhood Obesity Prevention Interventions Strategies. Mothers identified topics and strategies for future interventions to prevent childhood obesity among Hispanic families. Mothers were interested in learning more about feeding and nutrition (including breastfeeding, formula selection, and how to prepare baby food at home), sleep routines and sleep training, child weight gain, and normal child development. For topics related to screen time, mothers felt strongly that they needed more information that demonstrated a negative impact on vision or cognitive development in order to make behavior changes.

Almost all mothers showed interest in group classes to learn more about caring for their child. Mothers valued not just information but also hearing the experience of other mothers. Most mothers also wanted more easily accessible information from pediatricians. Text messaging, telephone support, email, health coaches, WIC parenting groups, and established Internet sources were reported as potential avenues for interventions. A few mothers were interested in home visits, and several reported interest in mailed brochures to reduce reliance on Internet access and enhance the accessibility of information for family members.

Family members were viewed as stubborn and difficult to change. Because of the influence of relatives on child feeding practices and childcare, some mothers noted that interventions should not just target mothers, they should also include fathers and other family members. Some mothers thought that interventions that provided evidence-based information in print or on the Internet would be the most convincing way to change their family members' habits.

4. Discussion

In this qualitative study of Hispanic mothers with children in the first 1000 days of life, we found that mothers were unaware of the critical role that weight status from gestation through 2 years of age plays in future development of childhood obesity. Mothers did not recognize that early introduction of cereals and purees, screen time, or insufficient sleep are modifiable early life risk factors for childhood obesity. We found that mothers desired childhood obesity prevention interventions based on health care and public health systems and wanted interventions to include extended family members.

Our study provides information about the origins of risk factors for childhood obesity and highlights opportunities to intervene during the earliest moments of life to prevent development of obesity risk factors among Hispanic families, a population that carries disproportionate burden of childhood obesity. Black non-Hispanic children are also affected by disparities in childhood obesity, and a recent qualitative study by Herring et al. similarly found that pregnant African-American women believed that physical symptoms of pregnancy impact gestational diet quality and high gestational weight gain is bad for maternal health [16]. However, unlike our findings, African-American women in Herring's study had many perceptions that encouraged high gestational weight gain and they did not believe that high gestational weight gain is harmful for infants [16]. Our study provides information to inform future culturally appropriate health messages for Hispanic women during pregnancy and early life.

Similar to our study, a prior content analysis of motivational counseling phone calls among predominantly non-Hispanic white women during the postpartum period found that mothers identified crying and fussiness as signs of hunger, supplemented with bottles immediately after feeds to ensure fullness, and fed their children to soothe overnight [17]. Our results suggest these feeding practices, which can promote overfeeding, may cross cultural boundaries.

Our research also extends previous findings among older Hispanic children to earlier stages in the life course. In a recent qualitative study of Mexican origin mothers with elementary school-aged children, Martinez et al. found that mothers felt primarily responsible for ensuring their children were well-fed [18]. In our study, we identified that other family members, such as fathers and grandmothers, are influential in child feeding patterns that increase childhood obesity risk. Similar to our results, another qualitative study in 2005-2006 by Lindsay et al. found that family members, particularly grandmothers, challenged eating habits that Hispanic mothers set for their children [19]. We also learned that mothers had limited confidence in their ability to influence behavioral change among other family members.

Unlike Lindsay et al., who found that Hispanic mothers believed that children should weigh more [19], we found that Hispanic mothers largely did not endorse the popular notion that "a chubby baby is a healthy baby." Social desirability bias could explain our findings, though it is more likely that our findings represent a shift in weight perception norms over the past several years secondary to widespread publicity on the dangers of obesity for adults and children.

Two of our findings were particularly striking. First, incorrect family beliefs surrounding infant taste development and satiety, as well as concerns regarding inadequate nutritional quality of breast milk and infant formula, promoted early introduction of solid foods. Introducing solid foods earlier than 4 months of age is an established risk factor for childhood obesity [12, 20] and accounts in part for Hispanic disparities in childhood obesity [8, 21]. Second, we found that all mothers firmly felt that screen time was important to learning and visual development for their infants and young children. Families also used screens to put their infants to sleep. A recent qualitative study on television use among Boston-area Hispanic and black non-Hispanic families with young children also found that families were unaware of the adverse health outcomes associated with television use [22]. Child screen time is associated with obesity, sleep disturbance, attention issues, and language delays [23]. The American Academy of Pediatrics discourages media use by children under age 2 years and recommends that pediatricians discuss these recommendations with parents [23]. Future obesity prevention interventions with Hispanic families should include culturallytailored messages to correct these beliefs and reduce early introduction of solids foods and screen time among infants and young children, including health communication insights.

Most existing qualitative research surrounding childhood obesity in Hispanic families has focused on feeding practices in school-aged children. Our study is unique in its inclusion of families at different stages in the life course and its examination of etiologies of established early life risk factors for obesity that are both dietary and nondietary in nature. Our study does have limitations. The participant sample is geographically restricted and thus could limit the ability to generalize our results. Also, all focus group participants were mothers and our findings do not include perspectives of fathers. However, any parent was eligible for enrollment and the ultimate inclusion of only mothers was likely a result of their role as primary caretakers in these families.

In summary, opportunities exist in the first 1000 days of life to improve Hispanic mothers' understanding of childhood obesity risk factors and the role of early life weight gain in later life obesity. Mothers identified interventions that link health care systems with public health systems, use multiple methods of delivery for intervention components, and include extended family members as potentially effective approaches to reduce obesity risk factors for Hispanic children early in life. Future interventions that prevent the development of obesity risk factors in the earliest stages of life and consider the social-contextual environment may reduce racial/ethnic disparities in childhood obesity and its adverse outcomes.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Blending Better Beverage Options: A Nutrition Education and Experiential Workshop for Youths

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Objective. To reduce intake of sugar-sweetened beverages (SSBs) in youths as a means to reduce obesity risk. *Methods*. Youths 5–14 years old attending a summer program were given a two-hour workshop addressing the sugar content in SSBs, the health risks from drinking SSBs, and hands-on preparation as well as tastings of low-sugar beverage alternatives. Data on usual intake of SSBs was obtained at baseline, and pre- and postprogram surveys were conducted to gauge change in knowledge and/or attitudes regarding SSBs. *Results*. There were 128 participants (63% male) in the program. SSBs were commonly consumed with over 80% reporting regular consumption (mean daily intake 17.9 ounces). Significant increase in knowledge regarding the sugar content of commonly consumed SSBs was achieved; however change in attitudes was not significant. The large majority of youths reported enjoying the workshop and intention to reduce intake of SSBs following program participation. *Conclusion*. SSBs are commonly consumed by youths. Knowledge regarding the sugar content of SSBs is easier to impart to youths than influencing attitudes held about these beverages. Long-term interventions that reach out to parents and address the widespread availability of SSBs are needed to influence resistant attitudes and beverage choosing behaviors in youths.

1. Introduction

An increase in the consumption of sugar-sweetened beverages (SSBs) and the prevalence of childhood obesity have occurred in tandem. In the United States (US) between 1977 and 2002 the increase in calories consumed from soft drinks and other sweetened beverages increased 230% and 170%, respectively [1]. Concurrently, the prevalence of childhood obesity increased threefold in the US, with those in minority and low-income groups experiencing higher prevalence rates [2, 3]. During this period, many other factors that increase obesity risk changed as well, such as an increase in sedentary activities, purchase of fast food, and sleep debt [4, 5]. However, SSBs are of special concern since the calories contained in this liquid form, for some reason, are not registered by the body, and therefore no dietary compensations are made following intake [6]. Instead paradoxically, researchers have found that when youths drink more SSBs it results in an increase in solid food consumption as well, with choices like pizza, burgers, and savory snacks often chosen [7]. Mathias et al. [7] found through analysis of data collected from the National Health and Nutrition Examination Surveys (NHANES) conducted between 2003 and 2010 that for every 100 kcalories of SSB consumed by 6–11-year-olds there was an increase in solid food consumed providing an additional 36 ± 14 kcalories. Youths 12–18 years of age revealed an intake of an additional 86 ± 10 kcalories in solid food form for every 100 kcalories of SSB product consumed. Recently, several reviews have illuminated the strong connection between obesity risk and SSB intake [8–10]; however weak potency of effect on interventions has called into question the absolute strength of this association [11].

In addition to an increased risk of obesity from consuming liquid calories, the high sugar content in SSBs has been associated with an increased risk of insulin resistance, dyslipidemia, type 2 diabetes mellitus, and cardiovascular disease [1, 6, 12]. Added sugars consumed from both liquid and solid sources are associated with body weight gain in youths at risk of developing obesity [6]; however Wang et al. [13] found in their group of 564 youths who were followed for two years that consuming sugar from liquid, but not solid, sources predicted a higher risk of developing impaired glucose homeostasis and glucose resistance. Reports spanning the past decade highlight increasing consumption of SSBs among children, adolescents, and teens [1, 4, 14, 15]. Recent estimates of the mean caloric contribution from SSBs range from 117 kcal/day to as much as 356 kcal/day, with calorie contribution variations based upon age category, sex, and ethnicity [14–17]. Those in minority and low-income groups have been identified as drinking greater amounts of SSBs [18]. It has also been found that approximately 5% of children and 16% of adolescents surveyed are heavy consumers of SSBs, with intakes at or exceeding 500 kcal/day [8]. SSBs are available to youths on the school campus as well as on the home front [17, 18]. However, researchers point to data supporting that the majority of SSBs are consumed at home [15, 17].

Public health experts have made a call for action in the form of educational interventions to address the excessive SSB intake in youths and subsequent adverse health issues [1, 9, 10, 14, 16, 17, 19]. The aim of the current study was to gauge impact on knowledge and attitudes regarding SSBs following a hands-on workshop for youths delivered during summer program hours. This experiential workshop addressed the sugar content of commonly consumed SSBs and included preparation and tasting of lower sugar alternatives. The study was given exemption status from Long Island University.

2. Methods

2.1. Setting and Participants. A convenience sample of youths who were enrolled in the summer program at a local boys and girls club participated in the nutrition education and blending better beverage options workshop. This program was provided to all attendees of the summer program at one boys and girls club in Long Island in New York State. All 128 summer camp participants were included in the workshop. Participants ranged in age from 5 to 14 years old. The workshop was delivered to approximately 20 participants at a time who were divided into small groups of 6–8 youths of similar age and were seated at one work table together with two undergraduate nutrition student volunteers.

2.2. Instrument. The survey instrument was developed by the study investigators and was based upon current literature [8, 16, 18] and designed to explore knowledge and beliefs about SSBs. The survey was modified to be age-appropriate; one version was created for 5–9-year-olds and another was developed for those who were 10–14 years of age. The same questions were asked, but the language was simplified and smile and frown faces were used for improved comprehension on the survey for the younger children. All participants were offered assistance with completion of the program surveys, and the younger participants were given one-on-one assistance when needed from undergraduate nutrition student volunteers. The survey was completed before the workshop began and following the end of the two-hour program for comparison.

2.2.1. Usual Intake of SSBs. Each participant was asked to report their usual intake within four commonly consumed beverage categories (soda, sports drinks, sugar-sweetened tea and juice, and energy drinks) before the start of the workshop. For each category the participant was asked to estimate his/her frequency of consumption per week and then to estimate quantity consumed per frequency. Sample cans and bottles and representative glassware were displayed at each table to assist the participants in estimating the quantity of SSBs consumed. Nutrition undergraduate student volunteers assisted the participants in completing the survey.

2.2.2. Knowledge of Sugar Content of SSBs. The survey included four questions regarding knowledge of sugar content (in teaspoon counts) of commonly consumed beverage items (16-ounce bottle of one-half sweetened iced tea and one-half lemonade, 12-ounce can of cola beverage, 20-ounce bottle of sweetened fruit punch, and an 8-ounce can of an energy drink). The participants were asked to select the amount (in teaspoons) of sugar from a list of four choices for each SSB item. The choices for each item were 3–5 teaspoons, 7–9 teaspoons, 10–12 teaspoons, or 15 or more teaspoons. The survey created for 5–9-year-olds included assistance in understanding the question by adding qualifying words for each selection with options listed as follows: 3–5 teaspoons, *a small amount*; 7–9 teaspoons, *a medium amount*; 10–12 teaspoons, *a large amount;* and 15 or more teaspoons, *a lot*.

2.2.3. Attitudes Held regarding SSBs. To record and gauge any change in attitudes held regarding SSB preferences, thoughts about health concerns associated with SSBs, and intention regarding avoidance of SSBs, participants were asked to respond to six statements at baseline and again following the intervention. Following each statement, such as "*I should drink less soda and sweetened beverages*," participants were directed to choose from a list of responses: strongly agree, agree, disagree, or not sure. The survey instrument completed by 5–9-year-olds included the following choices with accompanying faces to help them better understand and choose their response: yes definitely (broad smile), yes (smile), no (frown), and not sure (neutral).

2.2.4. Postprogram Feedback. On the postprogram survey participants were asked to respond to a question asking whether they had enjoyed participation in the program. Attendees were asked to respond to the following statement: "*I've enjoyed participating in the beverage workshop*." In addition, participants were asked to share their thoughts regarding intention to reduce intake of SSBs in the future by responding to the following statement: *"I think I will drink less sugar-sweetened beverages like soda because of what I've learned today*." Once again the 10–14-year-old participants were asked to select from the following responses: strongly agree, agree, disagree, and not sure; and 5–9-year-olds chose their answer from yes definitely (broad smile), yes (smile), no (frown), and not sure (neutral), using visual faces to help them better understand and choose their response.

2.3. Intervention. Each participant took part in a two-hour workshop held during summer program hours that was composed of two separate, yet related, components.

(1) Educational session revealing the sugar content of commonly consumed beverages and demonstration of adding a similar content of table sugar to water. Discussion of the health detriments associated with excessive sugar intake.

(2) A hands-on, experiential involvement in blending better beverage options, followed by recipe tastings. A discussion about how to make healthier decisions for beverages.

Undergraduate nutrition student volunteers assisted participants in completing the program surveys and served as facilitators for the workshop. Each volunteer attended a one-hour instructional training session conducted by the Principal Investigator prior to the start of the program.

2.3.1. Sugar Content Quiz and Demonstration. After completion of the baseline survey, each table of 6–8 participants took part in a guessing game and discussion about the sugar content of four popular beverage items led by an undergraduate nutrition student. Participants were asked to guess how many teaspoons of sugar were in each of four commonly consumed beverage items. After guessing, the nutrition student revealed the correct answer and asked the participants to count out sugar packets representing the amount of sugar contained in the item. A plate containing all the sugar packages was placed in front of the beverage item to offer a lasting visual image. This process was repeated for each of the four SSBs. When the process was completed for all beverages, the children were asked to view the four items on the table and to consider how much sugar would be consumed if all four SSBs were consumed in one day. The group added the total packages of sugar to achieve a grand total. Then the nutrition undergraduate students at each table led a demonstration showing how much sugar is added to liquid beverages by adding 15 teaspoons of sugar to a 20-ounce glass of water. This item was stirred and passed around for the participants to view the thick, cloudy substance that was created by simulating the amount of sugar often added to SSBs. An interactive discussion regarding the sugar content of SSBs and the health consequences of consuming too much sugar was held. Each nutrition undergraduate student was instructed to pose the following questions to the participants.

(1) Is anybody surprised about the amount of sugar in these beverages?

(2) Would anyone take a glass of water and add the same amount of sugar to it and then drink it?

(3) Do you think drinking so much sugar in these types of beverages is harmful to your health?

   (a) Nutrition students were instructed to highlight the association of high sugar intake with weight gain, diabetes, and dental caries.

   (b) A review of the concerns associated with the ingredients in energy drinks and why children should not drink these products was conducted.

(4) Would you like to make beverages to drink that are lower in sugar?

2.3.2. Blending Better Beverage Options: Tasting and Discussion. Participants were led in a hands-on preparation of four recipes: (1) fresh peach and orange infused water, (2) pineapple, mango, peach, and lime slush, (3) cranberry, pineapple, and lime fizzy, and (4) fresh strawberry and banana smoothie. The participants had the opportunity to taste all items they had prepared. The nutrition undergraduate students were instructed to ask for participant feedback about the taste, acceptability, and ease of preparation of lower sugar beverage alternatives. The importance of preparing beverages using diluted versions of 100% fresh fruit juices was stressed.

2.4. Analysis. The study, including instruments, protocols, and consent procedures, received exempt approval by the Institutional Review Board at Long Island University. Written parent consent was not required because the student survey portion of this project was classified as exempt. Survey data results were tabulated and compiled into a database and analyzed using STATA (SE 13) to provide descriptive statistics and analysis. In addition to the standard Chi-square tests the analysis includes t-tests for comparing two population proportions. Proportions are among the few measures which can be used for summarizing categorical data and provide an additional dimension to the analysis. Unlike a Chi-square test that tests for the association between qualitative variables using the entire contingency table, the t-test can be applied to test, for example, if the proportion of participants correctly answering the question on the pretest is statistically different from the proportion of participants correctly answering the question on the posttest. The test statistic for comparing two population proportions is $t = ((\widehat{p_1} - \widehat{p_2}) - (p_1 - p_2))/\sqrt{\overline{p}(1-\overline{p})(1/n_1 + 1/n_2)}$, where $\widehat{p_1} - \widehat{p_2}$ are sample proportions estimates, $p_1 - p_2$ are population proportions, and $\overline{p} = (x_1 + x_2)/(n_1 + n_2)$ is the weighted average of the two sample proportion estimates. All t-tests results are one-tailed tests in order to study if one proportion of respondents is higher than the other, rather than simply being different from each other which would be captured by the two-tailed test. In other words, the tests are to assess if the proportion of participants correctly answering the question on the posttest is higher than the proportion of participants correctly answering the question on the pretest. Level of significance was set at $P < 0.05$.

3. Results

3.1. Participants. Specific participant sociodemographic data were not obtained due to the study's exemption status. However, study participants were attendees of the local boys and girls club afterschool program. The attendees of the program are predominately Latino and African American and come

Table 1: Typical consumption of SSBs in youths attending a summer program.

Question	Response	5–9-year-olds number (%)	10–14-year-olds number (%)	Entire group number (%)
I drink soda				
Such as cola, ginger ale, Sprite, and Mountain Dew	Yes	60 (85.7)	51 (87.9)	111 (86.7)
	No	10 (14.3)	7 (12.1)	17 (13.3)
Mean times per week		2.37	2.09	2.25
Mean ounces consumed		9.91	11.1	10.45
Total mean ounces consumed per weeks		26.26	26.28	26.27
I drink sports drinks				
Such as Gatorade and Powerade	Yes	60 (85.7)	49 (84.5)	109 (85.2)
	No	10 (14.3)	9 (15.5)	19 (14.8)
Mean times per week		2.41	2.78	2.58
Mean ounces consumed		15.06	18.28	16.52
Total mean ounces consumed per weeks		42.54	63.03	51.83
I drink sugar-sweetened beverages				
Such as sweetened tea, fruit punch, and Sunny-D	Yes	57 (81.4)	47 (81.0)	104 (81.3)
	No	13 (18.6)	11 (19.0)	24 (18.8)
Mean times per week		2.84	2.81	2.83
Mean ounces consumed		12.16	11.98	12.08
Total mean ounces consumed per weeks		43.59	40.64	42.25
I drink energy drinks				
Such as Red Bull and Rockstar	Yes	11 (15.7)	20 (34.5)	31 (24.2)
	No	59 (84.3)	38 (65.5)	97 (75.8)
Mean times per week		0.3	0.78	0.52
Mean ounces consumed		1.49	3.94	2.6
Total mean ounces consumed per weeks		3.14	9.7	6.11
All beverages mean ounces		**113.87**	**139.64**	**125.55**

from single parent (51%) and low-income homes (76% come from families with incomes of less than \$33,000/year and 74% receive free or reduced fee lunch). A total of 128 surveys were distributed to participants, 100% were returned, and there were no missing responses or surveys that were deemed incomplete. Of 128 participants, 81 (63.3%) were male and 47 (36.7%) were female, with an average age of 9.3 years. Data were analyzed using the entire sample of 128 participants as well as by two age subgroups: age of 5–9 years and age of 10–14 years. There were 70 participants in the 5–9-year-old age group (41 male and 29 female) with an average age of 7.6 years and 58 participants in the 10–14-year-old age group (40 male and 18 female) with the average age of 11.3 years.

3.2. SSB Intake. The average amount of SSBs consumed per week for the entire sample was 125.6 oz. (17.9 oz. per day), with 113.9 oz. (16.3 oz. per day) for the 5–9 year old age group and 139.6 oz. (19.9 oz. per day) for the 10–14-year-old age group. A two-sample mean comparison t-test found no statistically significant difference in total SSB consumption between the two age groups. In addition, the difference in drinking soda and sugar-sweetened teas and juices was not significantly different between the two age groups. However, the older group was found to drink significantly more sports drinks and energy drinks compared to the younger group ($P < 0.05$; Table 1). The drinking habits of males versus females in both the 5–9-year- and 10–14-year-old age groups were not statistically different. However, males in the 10–14-year-old age group reported to drink twice as much soda as females in this age group, 31.1 oz. and 15.6 oz. per week, respectively, and are significantly more likely to drink energy drinks, 45% and 11%, respectively ($P < 0.05$).

3.3. Knowledge of Sugar Content in SSBs. To evaluate the level of knowledge obtained by attending the beverage workshop pre- and postintervention survey data were analyzed using the standard Chi-square tests for the association between two qualitative variables. For the entire sample of 128 participants, the Chi-square test for all four knowledge questions rejects the null hypothesis even when the P value is set at $P < 0.01$. Since all the scores have improved, it can be concluded that the intervention was successful in providing information to the participants. The same conclusion is obtained for the 10–14-year-old age subgroup. However, for the 5–9-year-old age group, the Chi-square test failed to reject the null for improvement in knowledge on the question about the sugar content in an 8 oz. can of an energy drink.

Results of the analyses of knowledge data using t-tests revealed that the proportion of participants who correctly answered the questions on the pretest for the entire sample of 128 participants is statistically different from the proportion of participants who correctly answered the questions on the posttest survey for questions 1 and 2 (sugar content in a 16 oz. serving of sweetened one-half iced tea and one-half lemonade; correct answer 10–12 teaspoons and in a 12 oz. can of cola soda; correct answer 10–12 teaspoons, resp.; Figure 1, panels (a) and (b)). However, for questions 3 and 4 (sugar content in a 20 oz. serving of sweetened fruit punch; correct answer 15+ teaspoons and an 8 oz. can of an energy drink; correct answer 7–9 teaspoons, resp., Figure 1, panels (c) and (d)), improvement in knowledge was increased, but not significantly. More precisely, for the age group of 10–14 years the scores on all four questions improved, while for the age group of 5–9 year olds only the scores for questions 1 and 3 (sugar content in a 16 oz. serving of sweetened one-half iced tea and one-half lemonade and the 20 oz. serving of sweetened fruit punch, resp., Figure 1, panels (a) and (c)) improved significantly.

3.4. Attitudes regarding SSB Intake. A great majority of participants either strongly agreed or agreed with the statement that they usually choose a glass of water when they are thirsty, that beverages with sugar are not good for them, and that they should drink less soda and sweetened beverages (Figure 2, panels (a), (e), and (f), resp.), both before and after intervention. In addition, most participants disagreed with the statement that soda is their favorite drink, that delicious drinks can be made using fresh fruit and beverages without added sugar, and that energy drinks are healthy (Figure 2, panels (b), (c), and (d), resp.). The differences between the pre- and postintervention responses to comments addressing attitudes, however, are not statistically different when Chi-square tests were applied. In all attitudinal comments posed study participants responded favorably regarding attitudes held on the preprogram survey except when responding to the comment that delicious drinks can be made using fresh fruit without added sugar. The majority of participants disagreed with this comment on the preintervention survey, and although there was an increase in the number of those who strongly agreed or agreed with this comment following the intervention, there was no statistically significant change in response following program completion.

Responses to one comment went in an unexpected direction for the comment addressing whether an energy drink was a healthy beverage option. The majority of participants disagreed that an energy drink is a healthy beverage option on both the pre- and postintervention surveys; however, unexpectedly less rather than more participants disagreed with the statement after intervention compared with the preprogram surveys. This result was mostly driven by the change observed in the younger participants in the 5–9-year-old age group, where more of them either strongly agreed or agreed that energy drinks are healthy for them after the intervention. One possible explanation for this might be due to their unfamiliarity with this type of SSB.

4. Discussion

This interactive workshop conducted during summer program hours held with youths 5–14 years of age queried usual intake of SSBs and focused on transmitting knowledge about the amount of sugar contained in commonly consumed beverage items and the potential health detriments associated with overconsumption. The workshop also included a hands-on preparation and tasting of several lower sugar beverage alternatives. In agreement with current literature [8, 14, 15], the youths attending this workshop reported regular consumption of SSBs. We found that the large majority of the youths who participated in the workshop reported regularly drinking soda (87%), sports drinks (85%), and sweetened teas and juices (81%). Approximately one-quarter of the participants (24%) reported drinking energy drinks, with a significant difference in consumption found in those 5–9 years of age (16%) in comparison with those 10–14 years old (35%). This finding is not surprising given the age of our participants as energy drinks are more commonly consumed by teens and young adults. However, there are many health concerns associated with consuming energy drinks and young children can be influenced by the intense marketing efforts for these products [20, 21]. Therefore, reports of any intake of energy drinks in youths 5–14 years of age are of concern and require further investigation focused on this specific group of SSBs. Of significance is that males were four times more likely than females to consume energy drinks. Based on our results 10–14-year-old males, in comparison with younger children and females, were more likely to consume energy drinks and should be targeted in future interventions aimed at eliminating consumption of this problematic beverage in at-risk youth populations.

Estimated mean intake of soda, sports drinks, sugar-sweetened drinks, and energy drinks per week, rounded to the nearest ounce, was 26, 43, and 44 ounces and 1 ounce, respectively, for 5–9-year-olds and 26, 63, 41, and 4 ounces, respectively, for 10–14-year-olds. We found that the mean intake of fluid ounces of SSBs in our group of participants translated into approximately 17.9 ounces of beverage per day, or a little over two 8-ounce servings. This quantity of SSB translates into approximately 224 kcalories. The mean calorie contribution from SSBs found in this study is similar to what others have reported as usual calorie contribution from SSB in children and adolescents [14–17]. Noted in our data, and in agreement with current trends reported, sports drinks are being consumed with increasing frequency [8]. Researchers have reported that parents in Latino communities may exhibit a misunderstanding regarding sports drinks as some have been found to report that they believe that these drinks are healthy options for their children [18]. This misunderstanding in a community at increased risk of obesity and glucose intolerance is concerning and can promote future health risks. Therefore, outreach to parents, particularly in Latino communities to inform them about the health risks regarding the sugar content of sports drinks, appears advisable [18].

Chi-square tests on the entire sample of participants revealed a significant improvement in knowledge of sugar

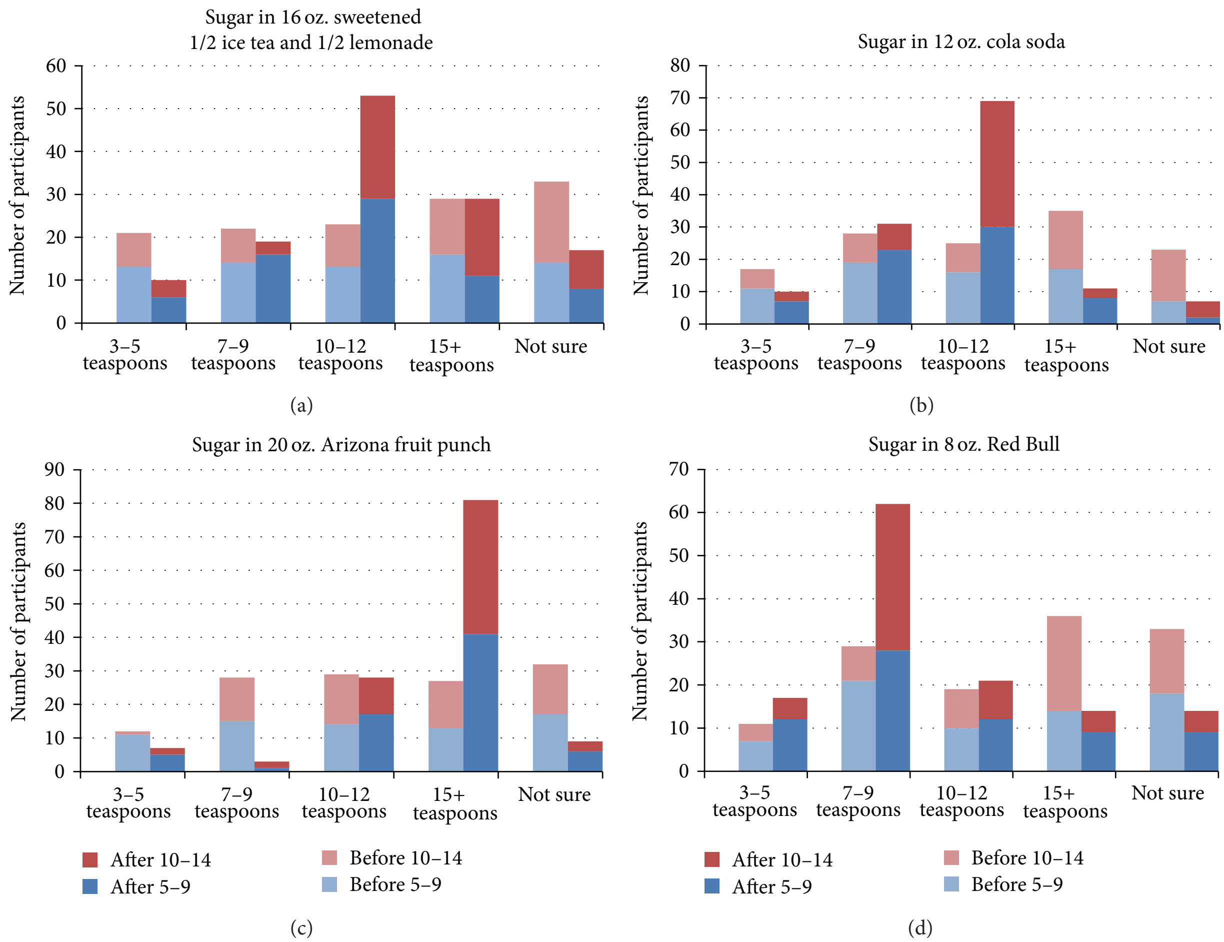

Figure 1: Baseline and postprogram SSB sugar content knowledge.

content for all four commonly consumed beverage items (iced tea/lemonade mix, cola beverage, sweetened fruit punch, and energy drink) between baseline and end of program. Since all the scores improved we conclude that the intervention was successful in providing information to participants.

Results of t-test analysis revealed improvement in knowledge after intervention for all four questions for 10–14-year-olds, but significance for 5–9-year-olds was only established for questions about the sugar content of iced tea/lemonade mix and sweetened fruit punch. These results are expected, since the participants in the age group of 10–14 years are more capable of understanding and retaining learned information. In addition, the older participants are also more likely to either consume and/or be familiar with cola beverages and energy drinks. In other words, the younger participants did improve their knowledge regarding the sugar content in all SSBs; however, for the sugar content in a 12 oz. can of cola and an 8 oz. can of an energy drink; correct answer 7–9 teaspoons, this change was not statistically different from the answers they provided in the pretest. It is not surprising that the younger aged participants did not remember the sugar content in energy drinks reviewed during the workshop as this is not a product that is widely consumed in this age category. It is possible that they did not register the information to memory due to lack of interest and familiarity with the product. Similarly, the younger participants would be more likely to drink sweetened fruit juice than cola beverages and this could explain the lack of significance found in change in knowledge for these beverage items.

Analyses of responses to six questions targeting attitudes about SSBs revealed no significant change in attitudes regarding beverage choice preference, thoughts about health concerns associated with SSBs, and wish to reduce SSBs following program participation. There are several factors that may explain the lack of change in attitude. One reason why there was not a considerable change found in participant attitudes might be that most participants already selected a favorable response prior to the intervention. Baseline surveys revealed that 85.7% of 5–9-year-olds and 81% of 10–14-year-olds reported that they choose water to drink when they are thirsty, and 84.3% of 5–9-year-olds and 65.5% of 10–14-year-olds reported that they knew that they should drink less SSBs. There were 57.1% of 5–9-year-olds and 74.1% of 10–14-year-olds who agreed that they thought beverages with added sugar were not good for them. However, it is possible that this comment may have been misunderstood by some who interpreted "not good for them" as not good in taste rather

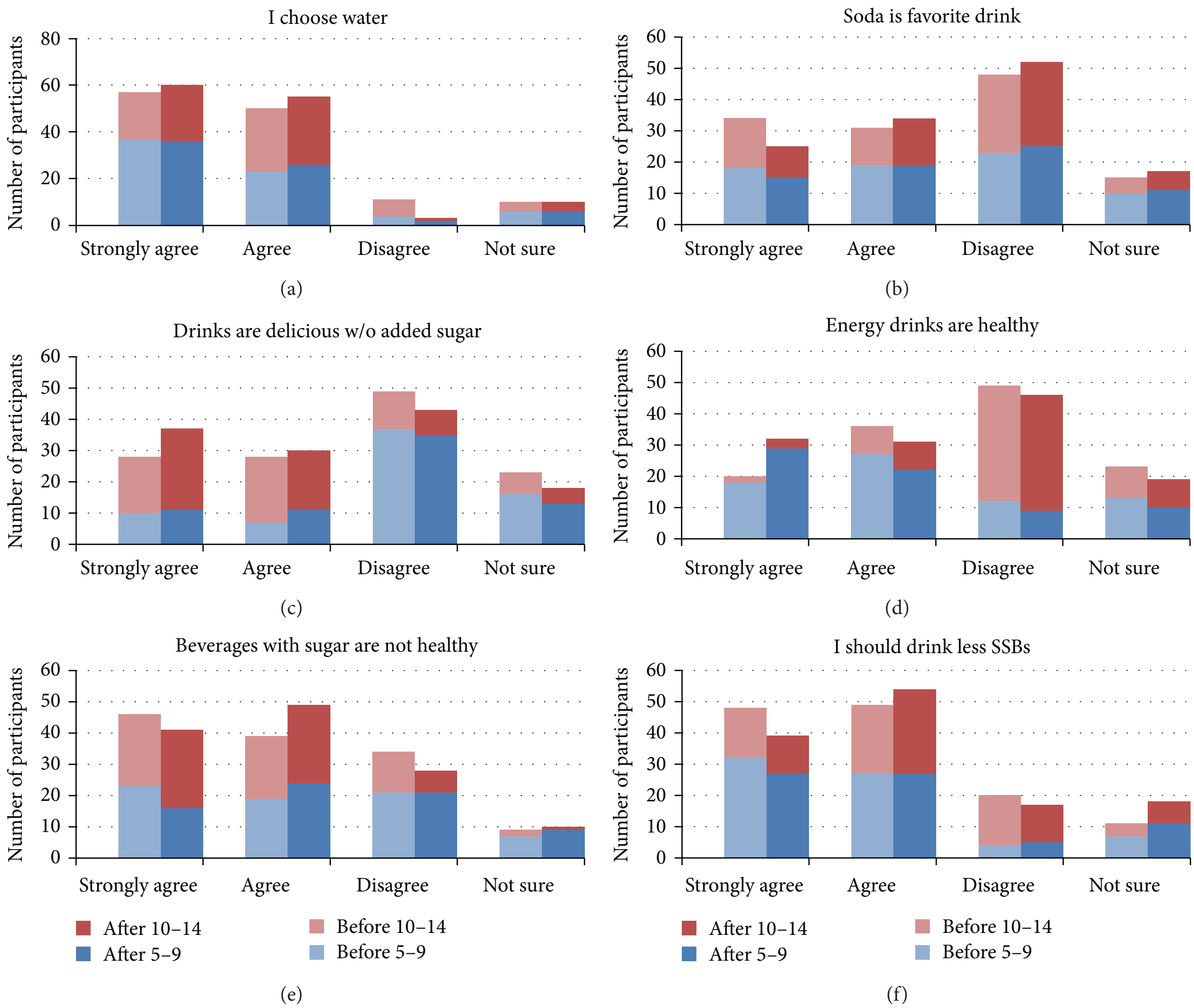

FIGURE 2: Baseline and postprogram responses to attitudinal statements.

than not good for health. There were volunteers who read and explained the concept of the comment to the participants, but there may still have been a misunderstanding of the intention. Therefore, response results to this comment need further investigation and when the comment is posed to participants in the future clarity can be enhanced by instead asking for response to *"Beverages with added sugar are not healthy for me."* Although not statistically significant impact of the program was evident as the results show that, following the intervention, more participants either strongly agreed or agreed with the statement that delicious drinks can be made using fresh fruit and beverages without added sugar (44.5% in the preintervention survey versus 52.3% in the postintervention survey). This trend in change of thought was particularly noticeable for the 10–14-year-old age group.

A significant percentage of children and adolescents seem to know they should reduce their intake of SSBs; however this knowledge does not translate into action. The preference for sweets is innate as well as learned, and so this biological response triggered by environmental availability may help to explain the resistance to behavior change in reducing SSB intake [22]. The strong desire for something sweet to drink and desire for a SSB in spite of known health risks were clearly stated by participants in a qualitative study conducted with college students [23]. College students are in an age category older than our participant sample and so even though they are more mature and should be able to better understand the risks of choosing to drink too many SSBs, the desire to drink what they wanted regardless was evident in the narrative captured by researchers [23]. Resistance to change in attitude and strong cravings for desired beverages make it difficult to see dramatic behavioral changes in attitudes held following short-term interventions. Despite these obstacles, Ebbeling et al. [24] report success in their study where they provided weekly deliveries of noncaloric beverages for 25 weeks to the homes of 53 children, aged 13–18 years. Compared to the control group the intervention group reduced their intake of SSBs by 84% and experienced a statistically significant reduction in body mass index (BMI) for those participants in the upper tertile for weight at baseline. Similarly, James et al. [25] conducted a year-long, school-based educational program for 644 schoolchildren in England who were 7–11

Table 2: Postprogram response: program evaluation and intention to change behavior.

	5–9 years number (%)	10–14 years number (%)	Total number (%)
I enjoyed participating in the beverage workshop			
Strongly Agree	43 (61.4)	32 (55.2)	75 (58.6)
Agree	17 (24.3)	20 (34.5)	37 (28.9)
Disagree	5 (7.1)	4 (6.9)	9 (7.05)
Not sure	5 (7.1)	2 (3.4)	7 (5.5)
I think I will drink less sugar-sweetened beverages like soda because of what I learned today			
Strongly Agree	34 (48.6)	19 (32.8)	53 (41.4)
Agree	23 (32.9)	26 (44.8)	49 (38.3)
Disagree	5 (7.1)	8 (13.8)	13 (10.2)
Not sure	8 (11.4)	5 (8.6)	13 (10.2)

years old, called *Ditch the Fizz*, and found a small reduction in BMI in the intervention group and a modest reduction in consumption of carbonated drinks. Additionally, Sichieri et al. [26] report a statistically significant reduction in consumption of carbonated beverages in their seven-month-long, school-based intervention ($n = 1134$) with 9–12-year-olds that focused on increasing water intake. The intervention group received classroom activities and water bottles and had promotional banners hung at the school. A statistically significant reduction in BMI was found only in those who were overweight at baseline and only in females. Evidently, small successes in reducing SSB intake in youth are achievable. However, long-term interventions that address the home, school, and afterschool environments may be needed to realize greater impact.

There were several limitations with this study. A convenience sample was used for the study with all the participants coming from one boys and girls club in one community in the US. The participants were predominately Latino and African American and therefore study results cannot be generalized to other groups. In addition, data collected were self-reported and may be skewed due to participant bias or poor recall. Finally and in hindsight, the comment addressing thoughts about whether sweetened drinks were "not good" for the participant was found to be ambiguously worded and may have been misinterpreted. Study strengths include the use of trained nutrition undergraduate students to assist participants with survey completion and the interactive design of the intervention. We engaged youths in the learning process offering an experiential workshop that allowed the participants to prepare and taste alternatives to SSBs and also provided strong visuals to enhance impact and learning. We did not just tell youth participants to avoid SSBs but instead had them prepare and taste no- and low-sugar alternatives. The results from the program evaluation reveal that participants enjoyed participating in this program, as 87.5% either strongly agreed or agreed with this statement. In addition, almost 80% of the participants either strongly agreed or agreed with the statement *I think I will drink less sugar-sweetened beverages like soda because of what I learned today;* 81.5% in the 5–9-year-old age group and 77.6% in the 10–14-year-old age group (Table 2).

5. Conclusion

Childhood obesity and subsequent health detriment remain a formidable public health concern. Weight gain from consuming sugar in liquid form, such as in SSBs, is particularly concerning as liquid calories are not registered by the body and therefore not compensated for with subsequent reduction in food intake. SSBs are ubiquitous and they have made their way into the daily diet of children as they are readily available at home, on the school campus, and at afterschool venues. In this two-hour, hands-on intervention study we found that consumption of SSBs was common in 5–14-year-olds in three major categories: soda, sports drinks, and sugar-sweetened teas and juices. Energy drinks were less commonly consumed; however 24% of the participants reported consumption. Energy drinks should not be consumed by youths and interventions that address avoiding consumption of energy drinks in this age group are needed.

Despite providing a relatively brief intervention we were able to show a significant increase in participants' retention of knowledge regarding the amount of sugar added to commonly consumed SSBs. Postprogram data revealed that the large majority of participants enjoyed the program and intended to reduce intake of SSBs following participation in the program. However, we were unable to significantly influence attitudes held regarding SSBs. Long-term interventions and programs that engage youths and reach out to parents as well as addressing the widespread availability of SSBs are needed in the future to influence resistant attitudes and beverage choosing behaviors in youths.

Disclosure

Veronika Dolar is the coauthor.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

The Intrauterine and Nursing Period Is a Window of Susceptibility for Development of Obesity and Intestinal Tumorigenesis by a High Fat Diet in *Min*/+ Mice as Adults

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We studied how obesogenic conditions during various life periods affected obesity and intestinal tumorigenesis in adult C57BL/6J-*Min* (multiple intestinal neoplasia)/+ mice. The mice were given a 10% fat diet throughout life (negative control) or a 45% fat diet *in utero*, during nursing, during both *in utero* and nursing, during adult life, or during their whole life-span, and terminated at 11 weeks for tumorigenesis (*Min*/+) or 23 weeks for obesogenic effect (wild-type). Body weight at 11 weeks was increased after a 45% fat diet during nursing, during both *in utero* and nursing, and throughout life, but had normalized at 23 weeks. In the glucose tolerance test, the early exposure to a 45% fat diet *in utero*, during nursing, or during both *in utero* and nursing, did not affect blood glucose, whereas a 45% fat diet given to adults or throughout life did. However, a 45% fat diet during nursing or during *in utero* and nursing increased the number of small intestinal tumors. So did exposures to a 45% fat diet in adult life or throughout life, but without increasing the tumor numbers further. The intrauterine and nursing period is a window of susceptibility for dietary fat-induced obesity and intestinal tumor development.

1. Introduction

Obesity is defined as an excess accumulation of adipose tissue. The rate of obesity has more than doubled over the past 20 years in most OECD countries [1]. More than half of the adult population are overweight (with body mass index (BMI) 25–30 kg/m^2) or obese (with BMI $\geq$30 kg/m^2), and about 18% of both genders are obese. Rates of overweight and obesity among children are also increasing; average reported overweight rates (including obesity) increased from 13% in 2001-2002 to 15% in 2009-2010 for 15-year-olds (based on age- and gender-specific cut-off points for BMI) [1]. Maternal obesity during pregnancy is also a serious health issue with a prevalence of obese adult women close to 30% in many of the OECD countries [2].

A parallel increase in overweight/obesity and many forms of cancer has been observed in most countries around the world in the past two to three decades. Cancer is now the second leading cause of mortality in the OECD countries [1]. In Norway, colon cancer is the second most prevalent cancer for women, after breast cancer, and the third most prevalent cancer for men, after prostrate and lung cancer [3]. Overweight and/or obesity are associated with increased risk, incidence, mortality, or poor prognosis for many types of cancer, including colon cancer [4–7]. Body fatness and abdominal fatness are both evaluated as convincing increasing risks of colorectal cancer [8, 9]. Obesity may be a contributing risk factor for increased susceptibility to environmental contaminants causing cancer.

The rapid rise of obesity is suggested to be driven mainly by environmental factors. Although it has been much focus on the role of the current diet whether as an obese child or adult, recent insights have also stressed the importance of nutrition during very early life in the development of metabolic disorders. The phenotype of an individual can be driven by *in utero* and early postnatal environmental conditions, determined by the nutritional status of the mother [10]. This has given rise to the perception of "developmental programming" and the concept "developmental origins of health and disease" (DOHaD). It is proposed that conditions present during a critical window of development can lead to permanent programmed alterations in physiological systems and adverse outcomes later in life [10, 11].

The "fetal origins of adult disease hypothesis" was originally put forward by David Barker and colleagues, which stated that environmental factors, especially nutrition, act in early life to program the risks for early onset of diseases such as hypertension, diabetes, coronary heart disease, metabolic disorders, and mental illnesses in adult life and premature death [10–12]. Although the initial fetal origins hypothesis was primarily concerned with undernutrition and malnutrition, recent epidemiological and animals studies have begun to examine the effects of overnutrition during critical periods of fetal development and the offspring's subsequent risk of developing the same chronic diseases associated with fetal growth restriction [13].

Maternal obesity is associated with numerous pregnancy-related complications and risks for both mother and child [14–16]. In addition to infertility, the mothers may have increased risk from obesity for hypertensive disorders, coagulopathies, gestational diabetes mellitus, respiratory complications, pre-eclampsia, thromboembolism, and so forth, in addition to miscarriage. The fetus has increased risk of large-for-gestational-age size, congenital malformations or perinatal mortality [14–16].

In this study, we have examined overnutrition, in the form of a high fat diet, during various periods of life in relation to the end points body weight and intestinal tumorigenesis in the mice as adults, using the C57BL/6J-*Min*/+ *(multiple intestinal neoplasia)* mouse as the experimental animal model. In addition, the wild-type (+/+) siblings were used to examine the effects on body weight and organ weights in older mice.

The *Min*/+ mouse is heterozygous for a germline nonsense mutation in the tumor suppressor gene *adenomatous polyposis coli (Apc)* leading to a truncated nonfunctional APC protein, and therefore develop numerous spontaneous intestinal tumors [17, 18]. *Apc* is a key component in the Wnt signaling pathway [19, 20]. The *Min* mouse is a model for the inherited disorder familial adenomatous polyposis (FAP), as well as for sporadic colorectal cancer, in humans [21–23], and develops multiple adenomas in the small intestine and to a lesser degree in the colon.

In addition to the effects on spontaneous intestinal tumors caused by the inherited mutated *Apc* gene in the *Min*/+ mice, the effect of obesity was also examined on tumors induced by the environmental (dietary) factor formed during cooking of meat and fish, the mutagenic, genotoxic and carcinogenic heterocyclic amine 2-amino-1-methyl-6-phenylimidazo[4,5-*b*]pyridine (PhIP) [24]. Previously, we have reported that PhIP increased intestinal tumorigenesis in adult C57BL/6J-*Min*/+ mice [25], and that the *Min*/+ mice were much more susceptible to PhIP if exposed neonatally [26, 27] than as young adults [25, 27]. Blood glucose levels were measured and a glucose tolerance test (GTT) was performed to study the hypothesis of disrupted blood glucose regulation as a link between obesity and intestinal tumorigenesis [28, 29]. The hormone leptin, which regulates food intake and energy expenditure, as well as having effects on immunity, including inflammation, and reproduction [30, 31], was measured in serum from the mice.

In this study, we have examined during which periods of life does exposure to obesogenic conditions in the form of a high fat diet have the most effect on body weight and susceptibility to disease, that is, intestinal tumorigenesis, as adults.

2. Materials and Methods

2.1. Mice. Female C57BL/6J-*Apc*$^{+/+}$ (wild-type) mice were mated with C57BL/6J-*Apc*$^{Min/+}$ males, using proven breeders having had a litter on a regular breeding diet (2018 Teklad Global 18% Protein Rodent Diet from Harlan Industries Inc., Indianapolis, IN, USA) before the experimental litters on special diets with 10% or 45% fat (described below). Both females and males were bred at the Norwegian Institute of Public Health, Oslo, Norway. C57BL/6J-*Apc*$^{Min/+}$ males were originally purchased from the Jackson Laboratory (Bar Harbour, ME, USA). To minimize the genetic drift from the colony at the Jackson Laboratory, both females and males in the breeding stock at our institute have been replaced regularly. Homozygous mutant *Apc*$^{Min/Min}$ (*Apc*$^{-/-}$) mice die during the embryonal stages [32]; therefore, only two genotypes were obtainable from these crosses. The *Min* mutation was propagated through males to avoid interference with pregnancy from any anemia caused by the intestinal adenomas in females [17].

Genotyping of the offspring for the *Apc* gene was performed with allele-specific polymerase chain reaction (PCR) using DNA extracted from ~2 mm^2 samples obtained by ear puncture for identification of individual mice at weaning, as described previously [33].

The mice were housed in air flow IVC racks (Innovive Inc., San Diego, CA, USA) in 100% PET plastic disposable cages on Nestpak Aspen 4HK bedding (Datesand Ltd., Manchester, UK) in a room with 12-h light/dark cycle, and controlled humidity (55 ± 5%) and temperature (20–24°C). Diet and water were given *ad libitum*.

The experiment reported in this paper was performed in conformity with the laws and regulations for animal experiments in Norway and was approved by the National Experimental Animal Board in Norway.

2.2. Experimental Diets. Diets of purified ingredients from Research Diets Inc. (New Brunswick, NJ, USA) were used. The D12451 diet, containing 20%, 35%, and 45% of kcal from protein, carbohydrates, and fat, respectively, was used as a high fat diet. The D12450H diet, containing 20%, 70%, and 10% of kcal from protein, carbohydrates, and fat, respectively, was used as a matching control low fat diet. The amount of sucrose was 17% of the calories in both diets. The high fat diet had 4.73 kcal/g, whereas the low fat diet had 3.85 kcal/g; that is, the high fat diet contained 22.9% more kcal per gram

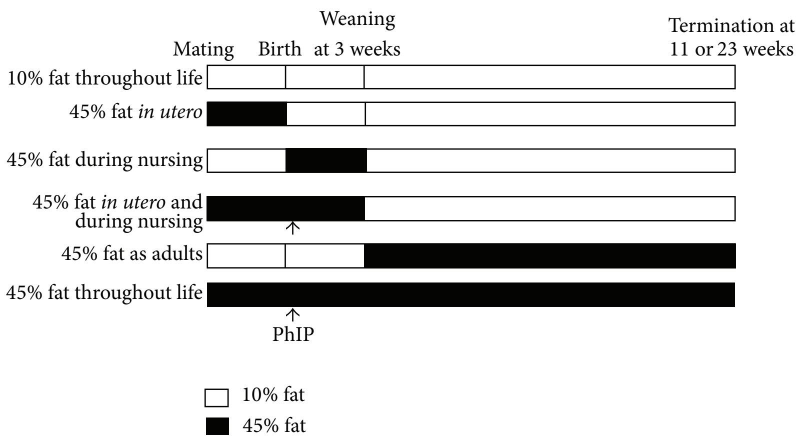


Figure 1: Experimental design. The mice were exposed to a 45% fat diet for combinations of three periods in life; (1) *in utero*, via the dams, (2) from birth to weaning, via milk during nursing, or (3) from weaning at 3 weeks to termination at 11 weeks of age (for *Min*/+ mice) or 23 weeks (for wild-type mice), to determine the most susceptible exposure period for development of obesity and intestinal tumorigenesis as adults. The effects of a 45% fat diet were studied on spontaneous tumorigenesis induced by the inherited mutation in the *Apc* gene and on tumors induced by the the food mutagen and carcinogen 2-amino-1-methyl-6-phenylimidazo[4,5-*b*]pyridine (PhIP). The mice in two experimental groups (marked with arrows) were given one s.c. injection of 25 mg/kg body weight of PhIP on days 3–6 after birth. In total, eight experimental groups were included in this experiment; a 10% fat diet throughout life as a negative control (10+10+10), a 45% fat diet *in utero* (45+10+10), a 45% fat diet during the nursing period (10+45+10), a 45% fat diet both *in utero* and during nursing (45+45+10), exposed to PhIP or not, a 45% fat diet as adults (10+10+45), or a 45% fat diet throughout life (45+45+45), exposed to PhIP or not.

diet. In order to avoid that the dietary treatment was unevenly spread out in time, we gave the first dam 10% fat diet, the second dam 45% fat diet, the third dam 10% fat diet, the forth dam 45% fat diet, and so on. Similarly, the litters of offspring were given either of the two diets after birth every other time and after weaning every other time until the necessary numbers in all experimental dietary groups were obtained (Figure 1). The number of litters (given in parentheses) in each treatment group was 10% fat diet throughout life (17), 45% fat diet *in utero* (17), 45% fat diet during the nursing period (14), 45% fat diet *in utero* and during the nursing period (19), 45% fat diet as adults (18), and 45% fat diet throughout life (21). For the groups also given PhIP, the number of litters was 45% fat diet *in utero* and during the nursing period (17) and 45% fat diet throughout life (17). The number of mice in each treatment group is given in the figures and tables for the various end points.

2.3. Dietary Carcinogen. 2-Amino-1-methyl-6-phenylimidazo[4,5-*b*]pyridine (PhIP) hydrochloride (CAS number 105650-23-5), catalogue number 163-15951, of >99% purity, was purchased from Wako Chemicals GmbH, Neuss, Germany. PhIP-HCl was dissolved in distilled water, and the pH was adjusted to approximately 4.0.

2.4. Experimental Treatment of Mice. The mice were exposed to a 10% fat control diet or a 45% fat diet during combinations of three periods of life; (1) *in utero*, via the dams, (2) from birth to weaning, via milk during nursing, and (3) from weaning at 3 weeks to termination at 11 weeks of age (the *Min*/+ mice) or 23 weeks (the wild-type mice), to determine the most susceptible exposure period for development of obesity and intestinal tumorigenesis as adults. The effects of a high fat diet were studied on spontaneous tumorigenesis induced by the inherited mutation in the *Apc* gene, and on tumors induced by the the food mutagen and carcinogen PhIP. The mice in two experimental groups were given one s.c. injection of 25 mg/kg body weight of PhIP on days 3–6 after birth. This dose of PhIP was chosen to give a suitable number of tumors above the spontaneous level based on previous experience [34]. In total, eight treatment groups were included in this experiment (Figure 1). The number of mice (n) in each treatment group is given for each end point in the figure legends and tables.

Blood was sampled by cardiac puncture under anesthesia with ZRF cocktail (containing 3.3 mg zolazepam, 3.3 mg tiletamine, 0.5 mg xylazine and 2.6 μg fentanyl per mL 0.9% NaCl) into Microvette serum/clot activator tubes (Sarstedt AS, Ski, Norway), and serum was obtained for analysis of the hormone leptin. Thereafter, the mice were sacrificed by cervical dislocation.

2.5. Recording of Body Weight and Feed Intake. Body weight of the dams was recorded at mating and weekly during the pregnancy and lactation periods. Body weight of the offspring was registered on day 3-4 after birth and thereafter weekly from weaning until termination of the *Min*/+ mice at 11 weeks of age, before onset of noticeable anemia caused by their tumors. The wild-type mice were terminated at 23 weeks of age, to study the effects on body weight and organ weights at older age. However, the body weight of the wild-type mice was also evaluated at 11 weeks of age, for comparison with the *Min*/+ mice terminated at 11 weeks. Body weight data were evaluated in three ways; as body weight at a specific age (at 11 weeks for the *Min*/+ mice and at 23 weeks for the wild-type mice), terminal body mass index (BMI) (also at 11 weeks for the *Min*/+ mice and at 23 weeks for the wild-type mice), and as body weight development expressed as area under the curve (AUC). The AUC was calculated for the offspring from age 3-4 days to week 11 (*Min*/+ and wild-type mice), and from week 12 to 23 (wild-type mice), as well as for the dams from mating to the end of pregnancy, using the trapezoidal rule in SigmaPlot 12.3 (Systat Software Inc., San Jose, CA, USA). Nasoanal length was also recorded at termination to calculate BMI as body weight/nasoanal length^2 (in g/cm^2). Feed intake was monitored by weighing feed in and out of the cages weekly for the dams during the pregnancy and lactation periods, and for the pups from weaning until termination.

2.6. Scoring of Small Intestinal and Colonic Tumors. Colon and small intestine were removed separately, rinsed in ice-cold phosphate buffered saline (PBS) and slit open along the longitudinal axis. Intestinal tissues were then spread flat between sheets of filter paper, and fixed for at least 48 h in 10% neutral buffered formalin prior to staining with 0.2% methylene blue (Sigma-Aldrich Norway AS, Oslo, Norway). Number, diameter and localization of tumors in small intestine and colon were scored by transillumination in an inverse light microscope at a magnification of ×20. The scoring was done in order of consecutive mouse numbers unaware of their treatment. Diameters of tumors were scored with an eyepiece graticule. Tumor position along the intestines was registered in cm from the stomach. For each experimental group, incidence of tumors (number of mice with tumors/number of mice in the group), tumor number (mean number of tumors/mouse ± SD) and tumor diameter in mm (mean of all tumors in all mice in the group ± SD) were calculated, for small intestine and colon separately. In addition, the size of the tumors was illustrated by curves of distributions of tumor size classes (of 0.25 mm tumor diameter intervals), calculated as mean number of tumors in each tumor size class for each treatment group. These curves were used to illustrate the effects of a 45% fat diet for various periods, which were calculated by subtracting the mean number of tumors in mice exposed to the control diet with 10% fat throughout life from the mean number of tumors in mice exposed to a 45% fat diet for various periods (Figure 10(a)). It was also done to illustrate the effect of PhIP on tumor size, by subtracting the mean tumor numbers in the corresponding dietary groups not exposed to PhIP from the mean number of tumors in the PhIP-treated groups (Figure 10(b)).

2.7. Absolute and Relative Organ Weights. The liver and spleen were dissected and weighed at termination, and the data are presented as absolute weight (in gram), or as relative weight (in %) calculated as absolute weight/body weight × 100.

2.8. Blood Glucose Measurements and Glucose Tolerance Test (GTT). Nonfasted blood glucose was measured with a glucometer (FreeStyle Freedom Lite, Abbott Diabetes Care, Inc., Alameda, CA, USA) in all the mice by puncture of the saphenous vein in the hind leg at two time points: at age 6 and 11 weeks (*Min*/+ mice) and at age 6 and 23 weeks (wild-type mice).

The glucose tolerance test (GTT) was performed on a subset of mice from each treatment group when they were 10 weeks old. The mice were fasted for 6 h from approximately 9 a.m. to 3 p.m. before i.p. injection of 2 g/kg body weight D-(+) glucose (Sigma-Aldrich, Norway, AS, Oslo). Blood glucose was measured 5 min before and 15, 30, 60 and 120 min after injection of glucose. The AUC was calculated from −5 to 120 min with the trapezoidal rule using Sigmaplot 12.3.

When readings were above 27.8 mmol/L and displaying HIGH on the glucometer, this value was used in the data analysis. This was not registered in any of the nonfasted blood glucose samples. In GTT, this occurred only for one *Min*/+ male given a 45% fat diet as adult at the 15 min time point, and for one *Min*/+ female given a 45% fat diet throughout life and PhIP, at 60 min. No samples in either end point had glucose readings below 1.1 mmol/L and showing LOW in the glucometer.

2.9. Leptin ELISA. The hormone leptin was measured in serum obtained from the mice at sacrifice. An ELISA kit (catalogue number MBS455345) from MyBioSource Inc. (San Diego, CA, USA) was used according to the manufacturer's instructions. Optical density (OD) was measured at 450 nm on a BioTek microplate reader (BioTek Instruments Inc., Winooski, VT, USA). Concentrations were calculated from standard curves on each plate. All samples were diluted 1 : 20 in PBS, pH 7.1. The limit of detection was 0.06 ng leptin/mL.

2.10. Statistical Analyses. The data are presented as mean ± SD and were analysed using SigmaPlot 12.3. The incidence of colonic tumors was analysed by Fischer exact test (two-tailed probability). For evaluation of all other data, analysis of variance (ANOVA) was used with an appropriate multiple comparison procedure. When testing the influence of a single factor, one-way ANOVA with the Holm-Sidak test for multiple comparisons was used for parametric data or the Kruskal-Wallis ANOVA on ranks with Dunn's test for multiple comparisons was used for nonparametric data. When testing the influence of two or three factors together the data were analysed by two- or three-way ANOVA, respectively, with the Holm-Sidak test for multiple comparisons. A P value of < 0.05 was considered statistically significant.

3. Results

3.1. The Dams' Age When Mated. There were no statistically significant differences between the mean age at mating for the dams given the various dietary combinations, being 121 days (10+10+10, $n = 17$), 108 days (45+10+10, $n = 17$), 120 days (10+45+10, $n = 14$), 122 days (45+45+10, $n = 19$), 114 days (10+10+45, $n = 18$), 104 days (45+45+45, $n = 21$), 112 days (45+45+10PhIP, $n = 17$), and 105 days (45+45+45PhIP, $n = 17$). There was a statistically significant difference ($P = 0.046$) between the mean age at mating of all the dams given a 10% fat versus a 45% fat diet, with mean age of 118 days (range 88–170 days) for the dams on the 10% fat diet and 110 days (range 82–186) on the 45% fat diet. However, this small difference most likely has no biological significance.

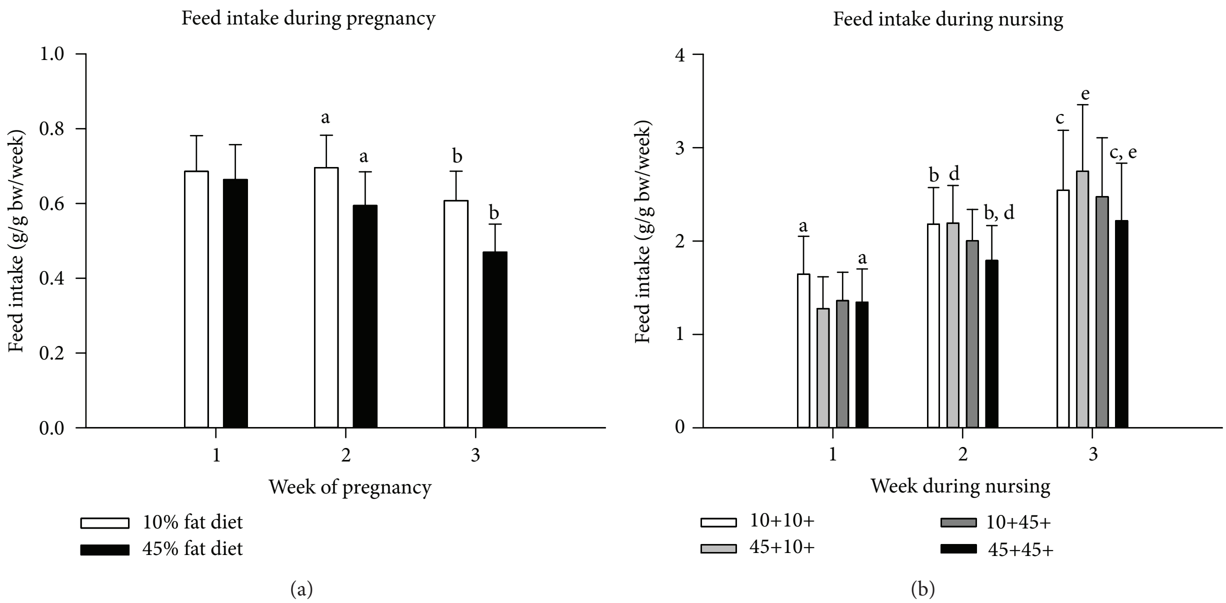


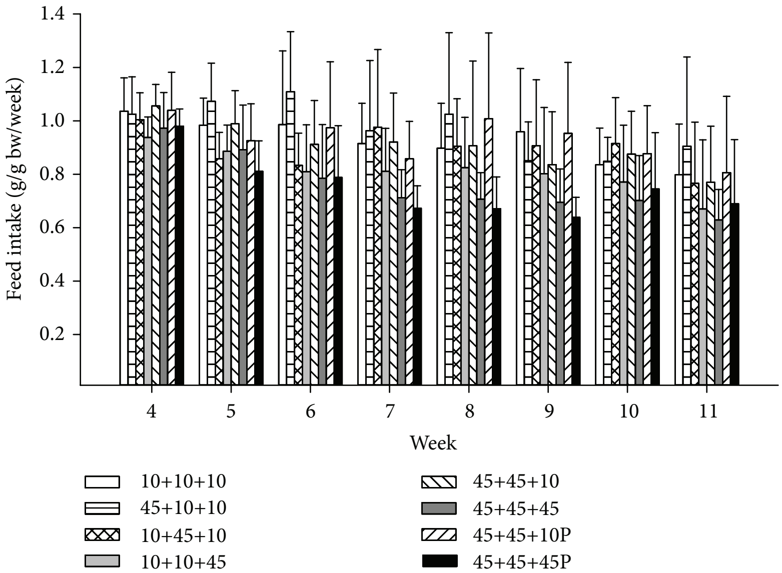
Figure 2: The feed intake of the dams during (a) pregnancy, that is, from mating to the end of week 3 of pregnancy ($n = 37–119$), and (b) the three week lactation period ($n = 12–69$), recorded as gram diet per gram body weight per week (mean ± SD). During pregnancy, the dams were given either a 10% fat (white columns) or a 45% fat diet (black columns). The data for the lactation period were stratified according to the four different combinations of the 10% fat or 45% fat diet during pregnancy and the 10% fat or 45% fat diets during the lactation period; 10+10+ (white columns), 45+10+ (light grey columns), 10+45+ (dark grey columns), 45+45+ (black columns), as explained in the legend to Figure 1. (a) [a,b]Significantly higher with a 10% fat diet versus a 45% fat diet within the same week. (b) [a,b,c]Significantly higher with a 10% fat diet during both pregnancy and nursing periods versus a 45% fat diet in the same periods within the same week. (b) [d,e]Significantly higher with a 45% fat diet during pregnancy and a 10% fat diet during nursing versus a 45% fat diet in both periods within the same week.

3.2. Breeding Efficiency on the Various Diets. There were no statistically significant differences in the resulting mean number of pups per litter in the various experimental dietary groups, being 6.1 (10+10+10, $n = 17$), 6.4 (45+10+10, $n = 17$), 7.4 (10+45+10, $n = 14$), 5.7 (45+45+10, $n = 19$), 6.9 (10+10+45, $n = 18$), 6.9 (45+45+45, $n = 21$), 6.2 (45+45+10PhIP, $n = 17$) and 6.2 (45+45+45PhIP, $n = 17$). Likewise, there were no statistically significant differences in the mean number of pups per litter between all litters given a 10% fat diet (6.8, $n = 49$) or a 45% fat diet (6.3, $n = 91$) during pregnancy.

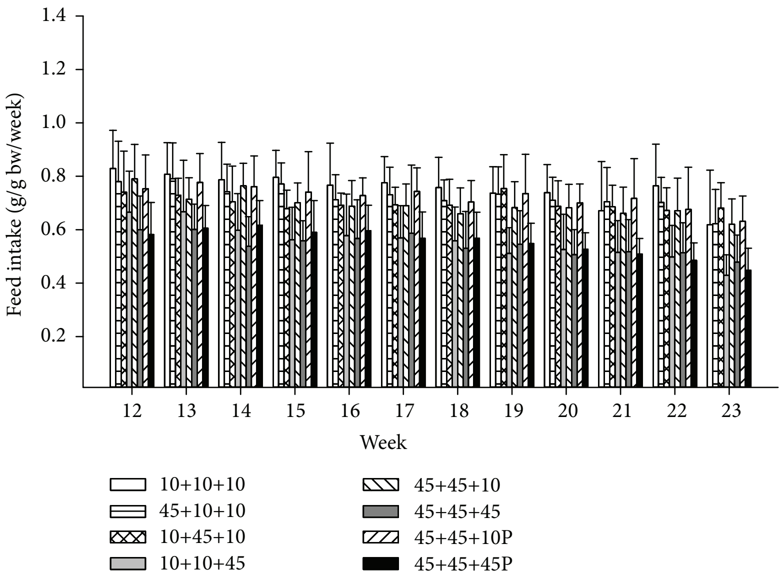
3.3. Feed Intake of the Dams during Pregnancy. The feed intake of the mice dams was recorded as gram feed per gram body weight per week for each of the three weeks of pregnancy (Figure 2(a)). The dams had a significantly higher feed intake per gram body weight in both week 1 and 2 compared with week 3, of both the 10% fat and 45% fat diets ($P < 0.001$ for all comparisons), and in week 1 compared with week 2 for the 45% fat diet ($P < 0.001$). The intake of feed per gram body weight was higher for the 10% fat diet than the 45% fat diet for all three weeks together, and for weeks 2 and 3 separately ($P < 0.001$ for all comparisons).

3.4. Feed Intake of the Dams during Nursing. The feed intake of the mice dams was recorded as gram feed per gram body weight per week for each of the three weeks of nursing (Figure 2(b)). The dams in all dietary groups had a significantly higher feed intake in both week 2 and 3 compared with week 1, and in week 3 compared with week 2, in all mice and in each experimental dietary group separately (P values were <0.001 to 0.012). The dams given a 45% fat diet during pregnancy and lactation periods had significantly lower feed intake than the dams given a 10% fat diet in both periods, in all time periods together and in weeks 1, 2 and 3, separately (P values were <0.001 to 0.018). The feed intake of the 45% fat diet compared with the 10% fat diet fat diet was 18.3, 17.9 and 12.8% lower in week 1, 2 and 3, respectively. The dams given a 45% fat diet during both pregnancy and the lactation period also had significantly lower feed intake than the dams given a 45% fat diet during pregnancy and a 10% fat diet during lactation, in all time periods together and in weeks 2 and 3, separately (P values were <0.001 to 0.010).

3.5. Feed Intake of the Min/+ and Wild-Type Offspring Aged 4 to 11 Weeks. The feed intake of the mice offspring (*Min*/+ and wild-type combined) after weaning was recorded as gram feed per gram body weight per week for each experimental group from week 4 to 11 for females (Figure 3(a)) and males (data not shown) separately. In general, females had a higher feed intake than males on gram body weight basis ($P < 0.001$), as has been found in our previous experiments (see [33], Ngo et al., 2014; unpublished results). This was seen in all treatment groups separately ($P = 0.004$ in the negative control group and the group given 45% fat diet throughout life and PhIP, and $P < 0.001$ for the rest of the groups), and in all weeks separately ($P = 0.007$ at week 4 and $P < 0.001$



(a)



(b)

Figure 3: The feed intake of the mice offspring after weaning was recorded as gram diet per gram body weight per week (mean ± SD) for each experimental group (n = 10–27), shown for (a) female *Min*/+ and wild-type mice combined, from 4 to 11 weeks of age, and for (b) wild-type males, from 12 to 23 weeks of age. Experimental dietary groups: 10+10+10 (open white columns), 45+10+10 (horizontally striped columns), 10+45+10 (cross-hatched columns), 10+10+45 (light grey columns), 45+45+10 (left upwards diagonally striped columns), 45+45+45 (dark grey columns), 45+45+10 + PhIP (right upwards diagonally striped columns), 45+45+45 + PhIP (filled black columns), as explained in the legend to Figure 1.

for the other weeks), except week 5 which did not reach significance. There was a general decrease in feed intake per gram body weight each week compared with the following week (Figure 3(a)), which was statistically significant (P values were 0.018 to < 0.001) except for weeks 7–10.

The mice given a 45% fat diet either as adults (for 8 weeks) or throughout life (for 11 weeks), with or without PhIP, had significantly lower feed intake per gram body weight per week than the other dietary groups receiving a 10% fat diet throughout life (for 11 weeks), or a 45% fat diet for shorter time, that is, only *in utero* (for 3 weeks), only during nursing (for 3 weeks) or during *in utero* and nursing (for 6 weeks), with or without PhIP (P values from 0.002 to < 0.001). PhIP did not affect the feed intake.

3.6. Feed Intake of the Wild-Type Offspring Aged 12 to 23 Weeks. The feed intake of the wild-type mice offspring was recorded as gram feed per gram body weight per week for each experimental group from week 12 to 23 for females (data not shown) and males (Figure 3(b)), separately. In general, wild-type females had a higher feed intake than males on gram body weight basis ($P < 0.001$), which was also seen in all treatment groups separately and in all weeks separately ($P < 0.001$ for all comparisons). There was generally a higher feed intake per gram body weight for the earlier weeks compared with the later weeks (Figure 3(b)), which was statistically significant in females for weeks 12, 14, 15 and 17 compared with each of weeks 20–23, and for week 12 also compared with weeks 18 and 19, and for week 15 also compared with week 19. Feed intake in week 16 was significantly higher compared with weeks 21–23, and feed intake in week 13 and weeks 18–22 was significantly higher than in week 23 only (P values were 0.048 to < 0.001). In males, there was a significantly higher feed intake in weeks 12 and 13 compared with each of weeks 20–23, and for weeks 14–22 compared with week 23 (P values were 0.041 to < 0.001).

As observed for the *Min*/+ and wild-type mice at weeks 4–11, the wild-type mice of both genders at weeks 12–23 given a 45% fat diet either as adults (for 8 weeks) or throughout life (for 11 weeks), with or without PhIP, had significantly lower feed intake per gram body weight per week than the other dietary groups receiving a 10% fat diet throughout life (for 11 weeks), or a 45% fat diet for shorter time, that is, only *in utero* (for 3 weeks), only during nursing (for 3 weeks) or during *in utero* and nursing (for 6 weeks), with or without PhIP ($P < 0.001$ for all comparisons). PhIP did not affect the feed intake.

3.7. Body Weight of the Dams during Pregnancy in Gram or as AUC. The increase in body weight in gram for the dams on either a 10% fat or a 45% fat diet from mating until the end of pregnancy is shown in Figure 4. The body weight was significantly increased each week compared with the previous week for dams on both 10% fat and 45% fat diets (P values were < 0.001 or 0.002 for all comparisons). The body weight was significantly higher in the dams on a 45% fat diet compared with a 10% fat diet at week 1 (3.3%, $P = 0.028$) and week 2 (7.2%, $P < 0.001$) of pregnancy, but not at mating (0.4%) and at week 3 at the end of pregnancy (2.0%).

Also when calculating the increase in body weight as AUC from mating until the end of pregnancy, the dams on a 45% fat diet had significantly higher AUC than the dams on a 10% fat diet ($P = 0.018$) (data not shown).

3.8. Body Weight in Min/+ and Wild-Type Mice Offspring in Gram or as AUC from Day 3-4 to Week 11. Body weight development (in gram) for both female and male *Min*/+ (Figure 5(a)) and wild-type (Figure 5(b)) mice of all treatment groups is shown from age 3-4 days to 11 weeks. The body weight development over time of the mice offspring was evaluated statistically as area under the curve (AUC) from day 3-4 to week 11 for *Min*/+ (Figures 6(a) and 6(b)) and wild-type (Figures 6(c) and 6(d)) mice for each dietary group. The *Min*/+ mice had a lower AUC compared with the wild-type mice in both females and males, and in mice both with and without PhIP treatment ($P < 0.001$ for all comparisons). Both *Min*/+ and wild-type male mice had larger AUC than females ($P < 0.001$ both comparisons), which was apparent

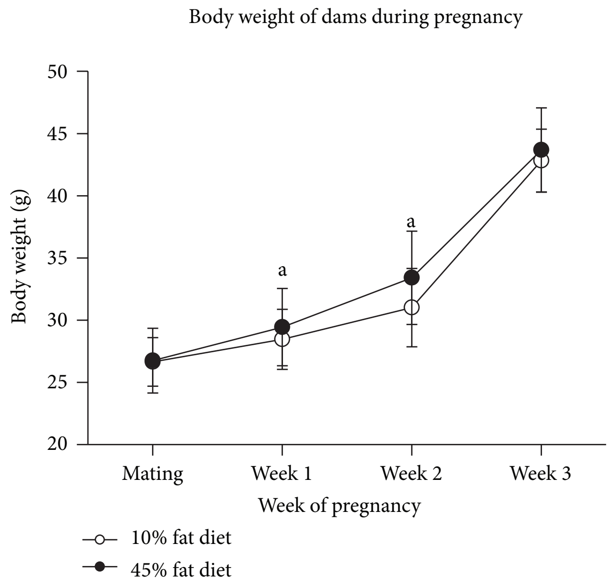


Figure 4: Body weight development (in gram) of dams during pregnancy, that is, from mating to the end of week three of pregnancy (mean ± SD). The dams were given either a 10% fat (open circles) or a 45% fat (filled circles) diet in this period. $n = 41$–123. [a]Significantly higher with a 45% fat diet versus a 10% fat diet in the same week.

in all dietary groups ($P < 0.001$ for all comparisons). *Min*/+ mice exposed to PhIP had lower body weight than mice not exposed to PhIP ($P = 0.027$), but PhIP did not affect the body weight in the wild-type mice.

In both *Min*/+ and wild-type mice of both genders, although slightly increased, exposure to a 45% fat diet *in utero* did not significantly increase the body weight as AUC compared with the negative control group given a 10% fat diet throughout life. Exposure to a 45% fat diet only during the nursing period significantly increased AUC compared with the negative control group ($P \leq 0.009$), except in the subgroup male wild-type mice. However, exposure to a 45% fat diet both *in utero* and during nursing significantly increased AUC compared with the negative control group when evaluating both genotypes and genders together ($P < 0.001$), but only in the subgroup of males for *Min*/+ and wild-type mice together ($P = 0.010$), whereas each genotype and gender separately did not reach significance. The exposure to a 45% fat diet during *in utero* and nursing did not increase AUC further compared with a 45% diet only during nursing. Thus, the effect of a 45% fat diet during the nursing period is more efficient in increasing the body weight than the exposure *in utero*.

The exposure to a 45% fat diet as adults did not increase AUC compared with the control group or any of the other exposure groups. The exposure to a 45% fat diet during nursing actually gave a significantly higher AUC than exposure as adults *in Min*/+ male mice ($P = 0.011$). In both *Min*/+ and wild-type mice of both genders, the exposure to a 45% fat diet throughout the whole life increased AUC compared with the negative control group ($P < 0.001$), and this was

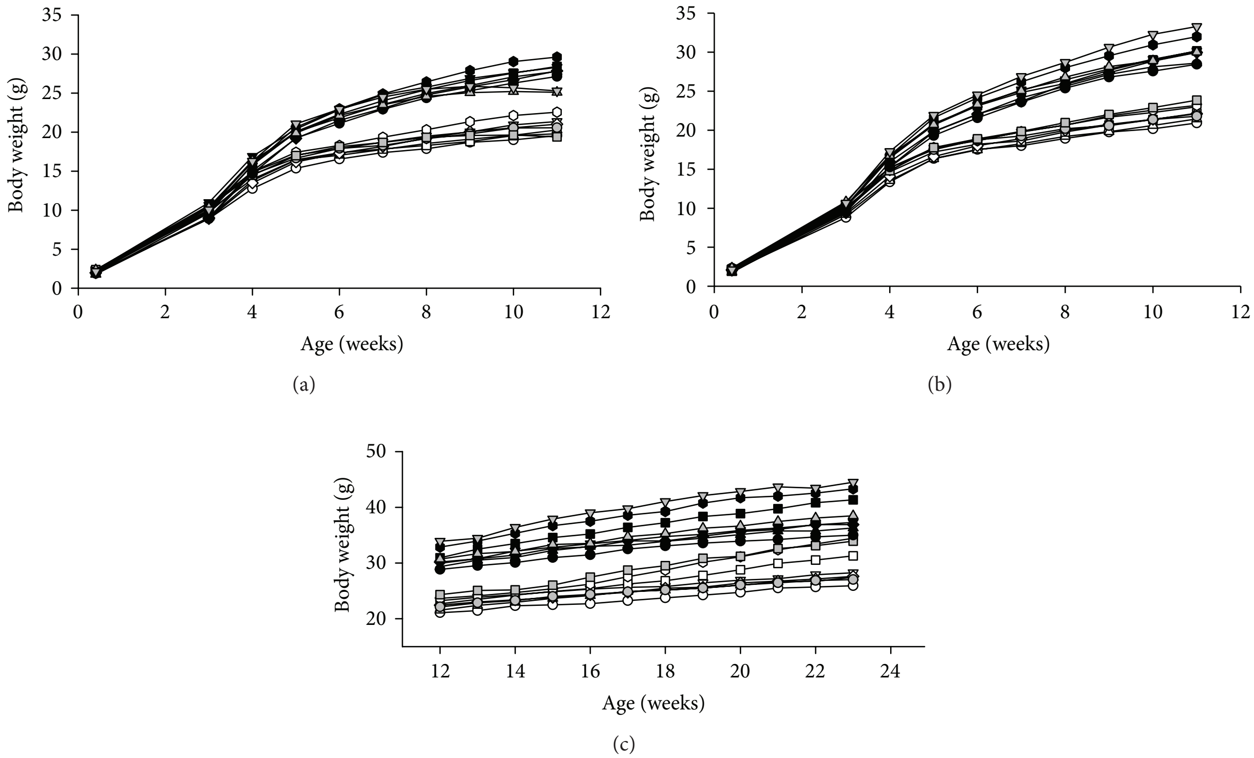


Figure 5: Body weight development (in gram) of female and male mice of all treatment groups is illustrated for (a) *Min*/+ and (b) wild-type mice from age 3-4 days to 11 weeks, and for (c) wild-type mice from age 12 to 23 weeks. The open white symbols are for untreated female mice; 10+10+10 (○), 45+10+10 (△), 10+45+10 (▽), 45+45+10 (□), 10+10+45 (◊), 45+45+45 (open hexagon), and the same filled black symbols are for untreated male mice. The PhIP-treated groups are marked with grey symbols; 45+45+10 PhIP (○) and 45+45+45 PhIP (□) in females, and 45+45+10 PhIP (△), 45+45+45 PhIP (▽) in males. The experimental groups are as explained in the legend to Figure 1. $n = 20$–46.

also the case for all subgroups; *Min*/+ females ($P < 0.001$), *Min*/+ males ($P = 0.001$), wild-type females ($P = 0.006$) and wild-type males ($P < 0.001$). Exposure to a 45% fat diet throughout life also increased AUC compared with the group given a 45% fat diet only *in utero* ($P < 0.001$), which was seen in female ($P = 0.024$) and male ($P < 0.001$) mice of both genotypes combined, and also in the subgroups female *Min*/+ mice ($P = 0.012$) and male wild-type mice ($P < 0.001$). Exposure to a 45% fat diet throughout life also increased AUC compared with exposure both *in utero* and during nursing ($P < 0.001$), which was seen in the female ($P = 0.024$) and male ($P = 0.030$) mice of both genotypes combined, and in the subgroup female *Min*/+ mice ($P = 0.022$). The comparison of a 45% fat diet throughout life with the group given a 45% fat diet only during nursing did not reach significance. However, AUC was significantly higher after exposure to a 45% fat diet throughout life compared with a 45% fat diet given only as adults ($P < 0.001$), which was seen in female ($P = 0.004$) and male ($P < 0.001$) mice of both genotypes combined, and also in the subgroups female ($P = 0.024$) and male ($P = 0.003$) *Min*/+ mice, and male ($P < 0.001$), but not female, wild-type mice.

Within the PhIP-exposed *Min*/+ mice, there was no significant difference in AUC between the exposure to a 45% fat diet during *in utero* and nursing compared with throughout life.

3.9. Body Weight in Wild-Type Mice Offspring in Gram or as AUC from Week 12 to 23. The *Min*/+ mice were terminated at 11 weeks of age, before negative health effects of their tumors become apparent. The wild-type mice were not terminated until 23 weeks of age to study the impact of the early life exposure to a 45% fat diet in older mice. The body weight in gram of the wild-type mice from age 12 to 23 weeks is illustrated in Figure 5(c). The body weight development of the wild-type mice offspring was evaluated statistically as AUC from week 12 to week 23 for each dietary group (Figures 6(e) and 6(f)). The male wild-type mice were significantly heavier than the females also at this age ($P < 0.001$). Similar to the wild-type mice from day 3-4 to week 11, there was no difference in AUC between wild-type mice given PhIP or left untreated from week 12 to 23.

In the wild-type mice of both genders, although slightly increased, exposure to the 45% fat diet only *in utero* did not significantly increase the body weight as AUC from week 12 to 23 compared with the negative control group given a 10% fat diet throughout life. The same was the case with exposure to a 45% fat diet only during nursing, or during both *in utero* and nursing. In wild-type mice, the exposure to a 45% fat diet as adults or throughout life increased AUC from week 12 to 23 compared with the negative control group, both in females ($P = 0.033$ and $P < 0.001$) and in males ($P < 0.001$ for both comparisons), respectively.

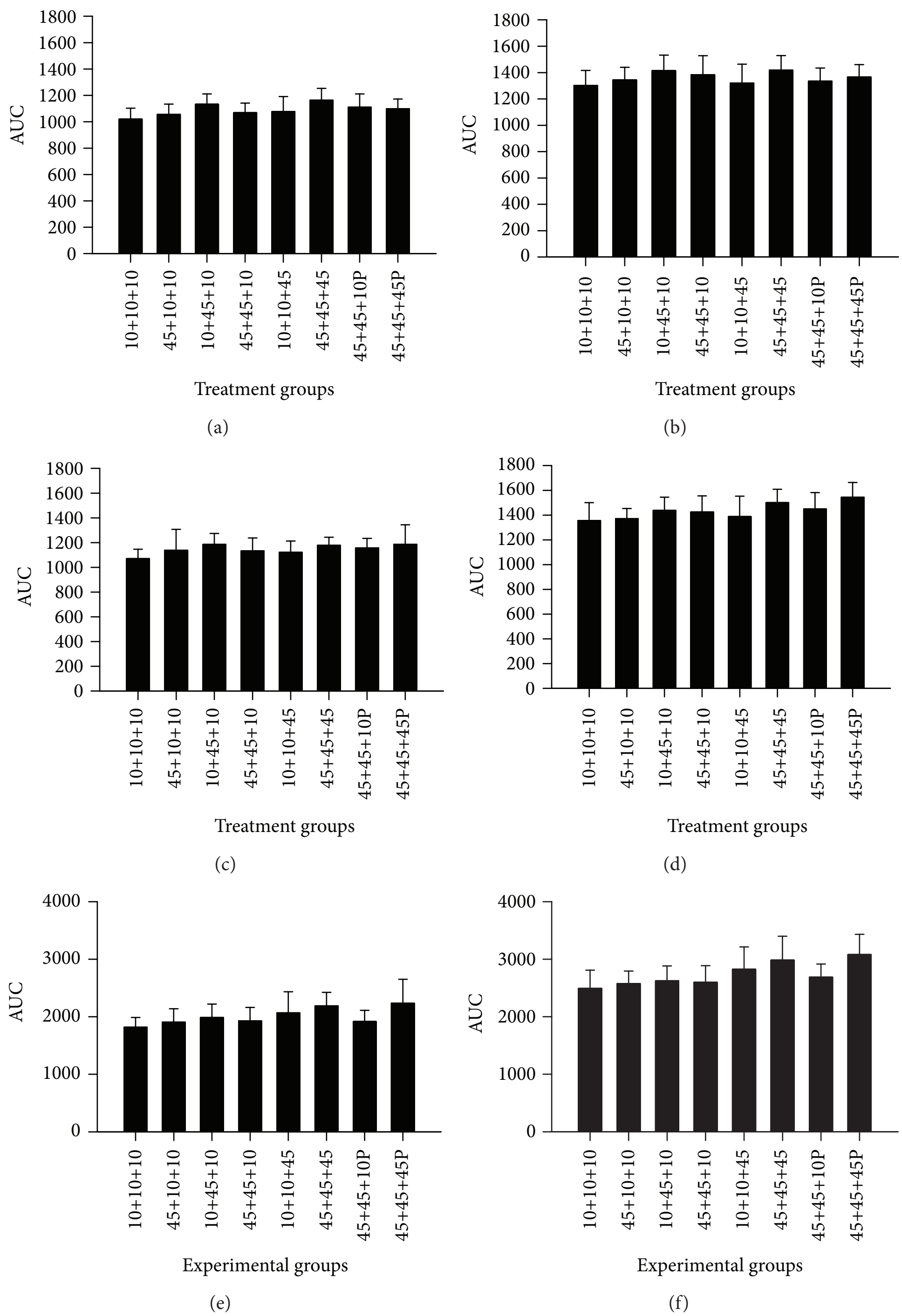


Figure 6: Body weight development as AUC (arbitrary units, mean ± SD) from age 3-4 days to 11 weeks for (a) *Min*/+ females, (b) *Min*/+ males, (c) wild-type females and (d) wild-type males, and from age 12 to 23 weeks for (e) wild-type females and (f) wild-type males. The experimental groups are as explained in the legend to Figure 1. $n = 20$–46.

Exposure to a 45% fat diet as adults also increased AUC compared with the group given a 45% fat diet only *in utero*, and both *in utero* and during nursing, in males ($P = 0.0013$ and $P = 0.046$, resp.), but not in females. Exposure to a 45% fat diet throughout life also increased AUC compared with exposure *in utero*, and *in utero* and during nursing, in females ($P = 0.008$ and $P = 0.009$, resp.), and in males ($P < 0.001$ for both comparisons). Exposure to a 45% fat diet throughout life also increased AUC compared with exposure only during the nursing period in males ($P < 0.001$), but not in females. The AUC results were not significantly different between a 45% fat diet as adults or throughout life in either gender.

Thus, the effects of an early exposure to a 45% fat diet both *in utero* and during nursing, or only during nursing, on AUC observed at age 3-4 days to 11 weeks, were no longer present when the wild-type mice had reached the age of 12 to 23 weeks.

3.10. Body Weight in Min/+ and Wild-Type Mice Offspring at a Specific Age (Week 11). Body weight at 11 weeks of age was evaluated for both *Min*/+ (Figure 5(a)) and wild-type mice (Figure 5(b)) of both genders. The *Min*/+ mice had significantly lower terminal body weight than the wild-type mice ($P < 0.001$). This was observed in the subgroups untreated mice ($P = 0.002$), PhIP-treated mice ($P < 0.001$), and in females ($P < 0.001$) and males ($P < 0.001$), separately. Male mice had significantly higher body weight at termination at 11 weeks compared with the female mice, in *Min*/+ mice, in wild-type mice, in untreated and PhIP-treated mice, and in all dietary groups ($P < 0.001$ for all comparisons).

Based on all mice and *Min*/+ mice separately, mice exposed to PhIP had a significantly lower terminal body weight compared with the untreated mice ($P < 0.001$ for both comparisons), but this was not seen in wild-type mice separately. PhIP affected body weight in both female ($P = 0.033$) and male *Min*/+ mice ($P < 0.001$), separately. This was also seen in the subgroups given 45% fat diet *in utero* and during nursing ($P = 0.019$) and throughout life ($P < 0.001$). Apparently, the tumor burden in the *Min*/+ mice, which is increased further with PhIP exposure, affects their body weight negatively, before overt signs of anemia and other negative health effects were observed. The same results were also observed in a previous study with this mouse model (Ngo et al., 2014; unpublished results).

Based on both *Min*/+ and wild-type mice, a 45% fat diet given *in utero* did not increase terminal body weight compared with the 10% control diet, whereas exposure during the nursing period only ($P < 0.001$) or during both *in utero* and nursing period ($P = 0.032$) did. In *Min*/+ or wild-type mice separately, a 45% fat diet given *in utero*, or during both *in utero* and nursing period, did not increase the body weight, whereas exposure during only the nursing period did ($P = 0.045$ for *Min*/+ mice, and $P = 0.033$ for wild-type mice). In female and male mice separately, none of these comparisons reached significance.

Based on both *Min*/+ and wild-type mice, exposure to a 45% fat diet only as adults increased the body weight compared with a 10% fat diet ($P = 0.012$), but not compared with exposure to a 45% fat diet *in utero*, during nursing, or during both *in utero* and nursing, whereas none of these comparisons reached significance in *Min*/+ and wild-type mice separately, or in female and male mice separately.

A 45% fat diet given throughout life to *Min*/+ and wild-type mice combined, or both genotypes separately, gave a significantly higher body weight compared with the negative control group given a 10% fat diet throughout life ($P < 0.001$ for all comparisons). Exposure to a 45% fat diet throughout life to the *Min*/+ and wild-type mice combined also had significantly higher body weight compared with all the other dietary groups (P values from 0.013 to < 0.01). This was also seen in *Min*/+ and wild-type mice separately (P values from 0.037 to < 0.01), except that in these cases the comparison with the mice given a 45% fat diet during nursing did not reach significance. A 45% fat diet throughout life gave a higher body weight in the subgroup female *Min*/+ mice compared with a 45% fat diet *in utero* ($P = 0.035$) and *in utero* and during nursing ($P = 0.002$), and in male wild-type mice compared with a 45% fat diet *in utero* ($P < 0.001$), *in utero* and during nursing ($P = 0.046$), and as adults ($P = 0.019$).

In the PhIP-treated *Min*/+ mice, a 45% fat diet given throughout life did not give significantly higher body weight compared with exposure to a 45% fat diet only *in utero* or during nursing, as it did in the untreated *Min*/+ mice ($P < 0.001$).

The 45% fat diet throughout life gave significantly higher body weight than the exposure to a 45% fat diet only in adult life ($P < 0.001$, $P = 0.004$ and $P = 0.0022$, in all mice, and *Min*/+ mice and wild-type mice, resp.).

3.11. Body Weight in Wild-Type Mice Offspring at a Specific Age (Week 23). The body weight of the wild-type mice from age 12 to 23 weeks is illustrated in Figure 5(c). Similar to the AUC results in wild-type mice from day 3-4 to week 11 and from week 12 to 23, there was no difference in terminal body weight at week 23 between mice given PhIP or left untreated. In these wild-type mice of both genders, although slightly increased, exposure to a 45% fat diet only *in utero* did not significantly increase terminal body weight at week 23 compared with the negative control group given a 10% fat diet throughout life. The same was the case with exposure to a 45% fat diet only during nursing, or both *in utero* and during nursing. The exposure to a 45% fat diet as adults or throughout life increased terminal body weight at week 23 compared with the negative control group, in both females and males separately ($P < 0.001$ for all comparisons).

Exposure to a 45% fat diet as adults increased terminal body weight compared with the group given 45% fat diet *in utero*, and both *in utero* and during nursing, in females ($P = 0.043$ and $P = 0.040$, resp.), and in males ($P < 0.001$ and $P = 0.006$, resp.), and compared with a 45% fat diet only during nursing in males ($P = 0.024$). Exposure to a 45% fat diet throughout life also increased terminal body weight compared with exposure *in utero*, during nursing, and both *in utero* and during nursing, in both females and males ($P < 0.001$ for all comparisons). The terminal body weight at 23 weeks was not significantly different between mice given a 45% fat diet as adults or throughout life in either gender.

Thus, the effects of an early exposure to a 45% fat diet observed during the *in utero* and nursing periods, or only during nursing, on terminal body weight at age 11 weeks, were no longer present when the wild-type mice had reached the age of 23 weeks.

3.12. Terminal BMI in Min/+ Mice Offspring at Week 11. When terminating the *Min*/+ mice at 11 weeks of age, terminal body weight and nasoanal length were recorded and BMI was calculated as body weight divided by the square of the nasoanal length (in g/cm^2) (data not shown). The male

Min/+ mice had significantly higher BMI at termination at 11 weeks compared with the females, and this was observed in all experimental dietary groups ($P < 0.001$ for all comparisons). Mice exposed to PhIP had a significantly lower BMI compared with the untreated *Min*/+ mice ($P < 0.001$), and this was seen in both mice given a 45% fat diet during *in utero* and nursing, and throughout life ($P = 0.009$ and $P < 0.001$, resp.), consistent with the other body weight results (AUC for body weight development and body weight at a specific time point).

None of the exposures to a 45% fat diet early in life; *in utero*, during nursing, or both *in utero* and during nursing, increased BMI compared with the negative control mice given a 10% fat diet throughout life, in either gender. The same results were found with exposure to a 45% fat diet as adults. The BMI after a 45% fat diet as adults was not significantly different from after a 45% fat diet *in utero*, during nursing, or during both *in utero* and nursing. A 45% fat diet given throughout life increased BMI compared with the negative control group, and the mice given a 45% fat diet *in utero*, in both genders separately ($P < 0.001$ and $P = 0.021$ in females, respectively, and $P = 0.013$ and $P = 0.032$, in males, resp.). A 45% fat diet given throughout life also increased BMI compared with a 45% fat diet *in utero* and during nursing in females ($P < 0.001$), and compared with a 45% fat diet during nursing ($P = 0.048$) and compared with as adults ($P = 0.011$) in males.

As opposed to body weight development as AUC from day 3-4 to week 11 and terminal body weight at 11 weeks, the end point terminal BMI at 11 weeks did not demonstrate early life as a sensitive period for obesity from exposure to a high fat diet in the *Min*/+ mice.

3.13. Terminal BMI in Wild-Type Mice Offspring at Week 23. The wild-type mice were terminated at week 23, and their BMI values were calculated (data not shown). The male wild-type mice had significantly higher BMI at termination at 23 weeks compared with the females, and this was observed in all dietary groups ($P < 0.001$ for all comparisons). At this time point, there was no longer any significant difference in BMI between mice exposed to PhIP or left untreated.

As found for *Min*/+ mice at 11 weeks, none of the exposures of wild-type mice to a 45% fat diet early in life; *in utero*, during nursing, or both *in utero* and during nursing, increased BMI compared with in the negative control mice given a 10% fat diet throughout life, in either gender. A 45% fat diet as adults increased the BMI compared with the negative control group ($P < 0.001$, for both genders), and compared with exposure to a 45% fat diet given *in utero* ($P = 0.014$ and $P = 0.003$) and both *in utero* and during nursing ($P = 0.042$ and $P = 0.040$), in females and males, respectively, and compared with a 45% fat diet given during nursing in females ($P = 0.047$). A 45% fat diet given throughout life increased BMI compared with the negative control mice, the mice given a 45% fat diet *in utero*, during nursing, and both *in utero* and during nursing, in both genders ($P < 0.001$ for all comparisons). The terminal BMI at 23 weeks was not significantly difference between exposure to a 45% fat diet as adults or throughout life.

Within the PhIP-exposed *Min*/+ mice, there was no significant difference in terminal BMI between the exposure to a 45% fat diet during the *in utero* and nursing period compared with throughout life, either in females or males.

As was found for *Min*/+ mice at 11 weeks of age, the end point terminal BMI at 23 weeks did no longer demonstrate the sensitive period for obesity early in life from exposure to a high fat diet in the wild-type mice.

3.14. Blood Glucose Levels. To test the hypothesis that obesity may affect intestinal tumorigenesis by disturbing the blood glucose regulation, blood glucose levels (nonfasted) were measured in all mice. This was done at weeks 6 and 11 in the *Min*/+ mice (Figure 7(a)), and at weeks 6 and 23 in the wild-type mice (Figure 7(b)). When compared at 6 weeks, the *Min*/+ mice had higher levels of blood glucose than the wild-type mice ($P < 0.001$), which was also found in our previous experiments (see [33], Ngo et al., 2014; unpublished results). The blood glucose levels were significantly higher in male compared with female *Min*/+ mice, at both 6 and 11 weeks, and in wild-type mice, at both 6 and 23 weeks, and in mice treated with PhIP or not ($P < 0.001$ all comparisons). It was also seen in all dietary groups for both time points together ($P < 0.001$ for all comparisons). The blood glucose results are presented for females and males separately (Figure 7).

The blood glucose levels measured at week 11 was significantly higher than at week 6, for females ($P < 0.001$) and for males ($P < 0.001$), for PhIP-treated ($P < 0.001$) and for untreated ($P = 0.018$) *Min*/+ mice. Blood glucose levels measured at week 23 were significantly higher than at week 6 for wild-type females ($P < 0.001$), whereas for males, the levels were higher at week 6 than week 23 ($P = 0.036$). Based on all values from *Min*/+ mice at 6 and 11 weeks, the PhIP-treated mice had higher blood glucose levels than mice not treated with PhIP ($P = 0.004$), which was also observed in a previous experiment (Ngo et al., 2014; unpublished results), whereas this effect of PhIP was not significant for the wild-type mice at weeks 6 and 23.

Exposure to a 45% fat diet only *in utero*, during nursing, or both *in utero* and during nursing, did not significantly increase blood glucose levels compared with the negative control group given a 10% fat diet throughout life, neither in *Min*/+ mice or wild-type mice at any time point.

Based on both genders at 6 and 11 weeks, a 45% fat diet given in adult life significantly increased the blood glucose levels compared with the control diet ($P = 0.038$) and exposure to a 45% fat diet during nursing ($P = 0.009$), but not compared with exposure to a 45% fat diet *in utero*, or both *in utero* and during nursing, in the *Min*/+ mice. Based on both genders at 6 and 23 weeks, a 45% fat diet given in adult life significantly increased the blood glucose levels compared with the control diet ($P = 0.006$), exposure to a 45% fat diet *in utero* ($P < 0.001$) and during nursing ($P = 0.033$), but not compared with exposure to a 45% fat diet both *in utero* and during nursing, in the wild-type mice. Based on both 6 and 23 weeks, a 45% fat diet given in adult life to female wild-type mice separately significantly increased the blood glucose level compared with the control diet ($P = 0.030$), exposure to a 45% fat diet *in utero* ($P < 0.001$), during nursing ($P = 0.019$),

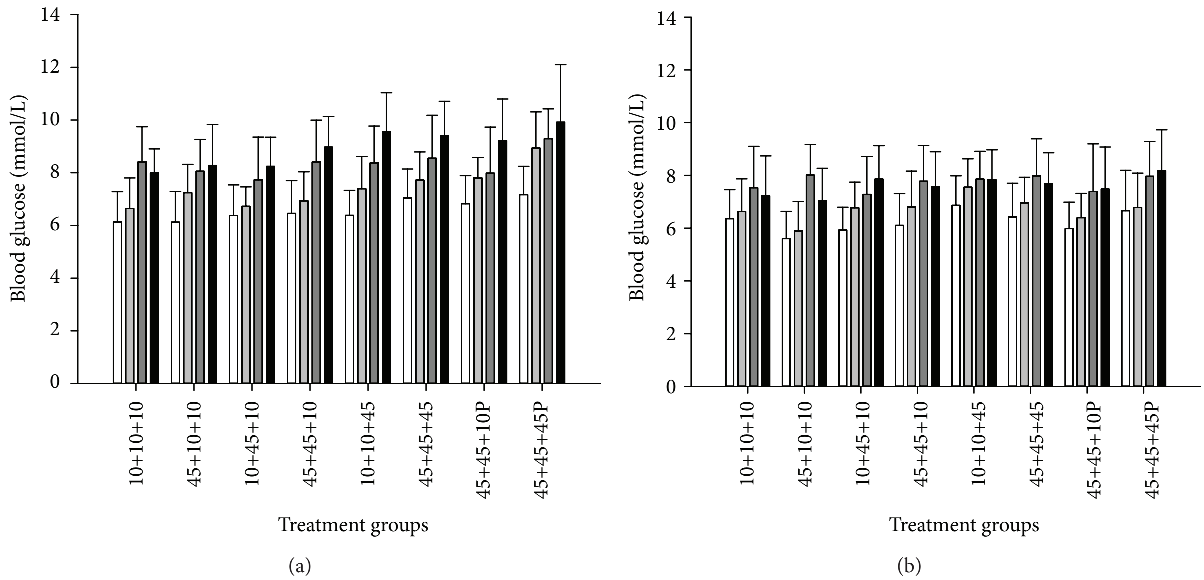


Figure 7: Nonfasted blood glucose levels (mmol/L, mean ± SD) for (a) *Min*/+ mice; females at 6 and 11 weeks and males at 6 and 11 weeks, (b) wild-type mice; females at 6 and 23 weeks and males at 6 and 23 weeks, shown for both genotypes with columns in white, light grey, dark grey and black color, respectively. P = PhIP. The experimental groups are as explained in the legend to Figure 1. $n = 9$–46.

and also compared with exposure to a 45% fat diet both *in utero* and during nursing ($P = 0.018$). In male wild-type mice separately, there were no statistically significant effects of a 45% fat diet given in adult life.

Based on both genders at 6 and 11 weeks, a 45% fat diet given throughout life significantly increased the blood glucose levels compared with the negative control group ($P < 0.001$), the group exposed to the 45% fat diet *in utero* ($P = 0.001$), and during nursing ($P < 0.001$), but the differences were not statistically significant compared with exposure to a 45% fat diet both *in utero* and during nursing, or as adults, in the *Min*/+ mice. Based on both genders at 6 and 23 weeks, in the wild-type mice a 45% fat diet given throughout life significantly increased the blood glucose level compared with the group exposed to the 45% fat diet *in utero* ($P < 0.001$), but the differences were not statistically significant compared with the negative control group, exposure to a 45% fat diet during nursing, both *in utero* and during nursing, or as adults. Also based on both 6 and 11 weeks, in female wild-type mice separately a 45% fat diet given throughout life significantly increased the blood glucose levels compared with the group exposed to the 45% fat diet *in utero* ($P = 0.001$), whereas the comparisons with the other groups did not reach significance. In male wild-type mice separately, none of the various dietary groups were significantly different. At 6 weeks separately, none of the comparisons with the 45% fat dietary groups reached significance compared with the control group, and at 11 weeks separately, the only significant difference was between the 45% fat diet throughout life compared with the control group ($P = 0.031$).

A shorter exposure to a 45% fat diet early in life, that is, *in utero*, during nursing, or both *in utero* and during nursing, was apparently not able to affect the blood glucose levels, whereas a longer exposure to a 45% fat diet as adults or throughout life did increase the blood glucose levels. However, exposure to a 45% diet as adults, and not throughout life, increased blood glucose levels significantly more than exposure both *in utero* and during nursing only in the subgroup of female wild-type mice evaluated at 6 and 23 weeks ($P = 0.018$).

3.15. Glucose Tolerance Test (GTT). To get a clearer picture of the effect on blood glucose regulation by the various dietary combinations, GTT was performed at 10 weeks on a subset of mice from each treatment group in a fasted state. A larger area under the curve (AUC) in the glucose tolerance test indicates that the mice have reduced ability to clear the injected glucose from the blood. As for the nonfasted blood glucose levels, significantly larger AUC was found in the *Min*/+ mice (Figures 8(a) and 8(b)) compared with the wild-type mice (Figures 8(c) and 6(d)) ($P < 0.001$). And likewise, males had significantly higher AUC compared with females ($P < 0.001$), which is especially noticeable in the wild-type mice (Figures 8(c) and 6(d)).

Blood glucose AUC was higher in PhIP-exposed mice compared with mice not given PhIP after exposure to a 45% fat diet throughout life ($P < 0.001$), but not after exposure to a 45% fat diet *in utero* and during nursing (Figure 8).

The early exposure to a 45% diet *in utero*, during nursing, or during both *in utero* and nursing, did not differ from the control group given a 10% diet throughout life (Figure 8). The mice in the groups exposed to a 45% fat diet as adults or throughout life had significantly higher AUC than the negative control group ($P < 0.001$ for both comparisons), and the mice exposed to a 45% fat diet either during adult life or throughout life also had significantly higher AUC compared with all the other treatment groups, including the group given a 45% fat diet both *in utero* and during nursing ($P = 0.002$ or

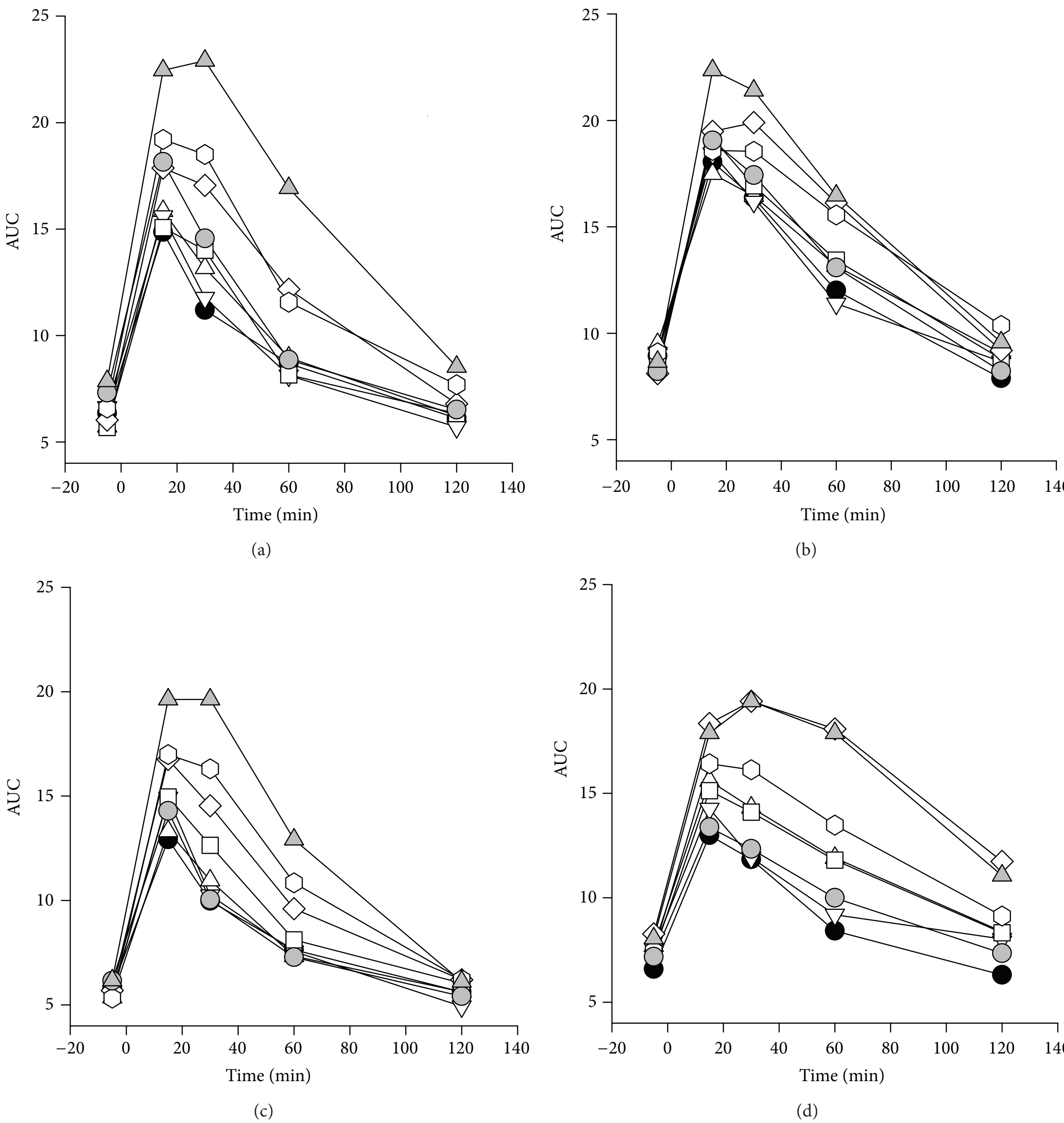


Figure 8: Mean fasted blood glucose levels at age 10 weeks as area under the curve (AUC) (arbitrary units) in the glucose tolerance test in (a) female and (b) male *Min*/+ mice, and in (c) female and (d) male wild-type mice. The symbols for the untreated mice of both genders are: 10+10+10 (●), 45+10+10 (△), 10+45+10 (▽), 45+45+10 (□), 10+10+45 (◊), and 45+45+45 (open hexagon), and the symbols for the PhIP-treated mice are in grey color; 45+45+10 PhIP (○) and 45+45+45 PhIP (△). The experimental groups are as explained in the legend to Figure 1. $n = 9$–16.

$P < 0.001$ for all comparisons) (Figure 8). The two dietary groups exposed to a 45% fat diet either during adult life or throughout life did not have significantly different AUC.

These GTT results essentially confirmed the results obtained by measuring blood glucose in a nonfasted state.

According to WHO [35], diagnostic criteria for humans with impaired glucose tolerance (IGT) are 7.8–11.1 mmol/L of glucose measured 2 h after an oral dose of 75 gram glucose, and levels above 11.1 mmol/L confirm diabetes. Regarding these levels also relevant for mice, we found IGT at the 2 h time point in the GTT in 8% and 23% (10+10+10), 5% and 69% (45+10+10), 0% and 68% (10+45+10), 27% and 60% (45+45+10), 13% and 82% (10+10+45), 23% and 70% (45+45+45), 10% and 50% (45+45+10 PhIP), and 32% and 92% (45+45+45 PhIP) of the female and male mice, respectively (treatment groups in parentheses). A diabetic level of glucose at the 2 h time point in the GTT was found in 0% and 0%, 0% and 7%, 0% and 5%, 5% and 5%, 0% and 27%, 0% and 22%, 0% and 0%, and 5% and 25% of the female and male mice in the same treatment groups as above, respectively.

3.16. Small Intestinal Tumors. All mice had small intestinal tumors (adenomas), independent of dietary or carcinogenic exposures, confirming 100% incidence of small intestinal tumors as is commonly found in the *Min*/+ mice [25–27, 33]. The number of small intestinal tumors was not significantly different between the genders, thus the data for males and females are presented together (Figure 9). Although slightly increased, exposure to the 45% fat diet only *in utero* did not significantly increase the number of small intestinal tumors compared with the negative control group given a 10% fat diet throughout life. Exposure to a 45% fat diet only during the nursing period was significantly increased compared with the negative control group ($P < 0.05$). However, exposure to a 45% fat diet both *in utero* and during nursing, significantly increased the number of small intestinal tumors further, compared with the negative control group ($P < 0.05$), and compared with a 45% diet only *in utero* ($P < 0.05$), but not compared with only during nursing. Thus the effect of a 45% fat diet during the nursing period is more efficient in increasing the tumor number than the exposure *in utero*.

Both exposure to a 45% fat diet in adult life or throughout life gave a significant increase in small intestinal tumors compared with the negative control group, the group given a 45% fat diet *in utero*, and the group given a 45% fat diet only during nursing ($P < 0.05$ for all comparisons). However, exposure to a 45% fat diet in adult life or throughout life did not significantly increase the number of small intestinal tumors compared with the early exposure during both the *in utero* and nursing periods, showing the importance of early life exposure for intestinal tumor development by a high fat diet. Unexpectedly, the exposure to a 45% fat diet throughout life did not increase the number of small intestinal tumors compared with this exposure only during adult life.

To compare the effects of a 45% fat diet on spontaneous tumorigenesis with the effect on carcinogen-induced mutation in or loss of the remaining inherited wild-type *Apc* allele, two of the experimental groups were treated with the food mutagen and carcinogen PhIP. These groups were either exposed to a 45% fat diet both *in utero* and during nursing or a 45% fat diet throughout life. There were no gender differences in the PhIP-treated groups or the control groups without PhIP, and thus the data for males and females are presented together (Figure 9). Both of the dietary groups treated with PhIP showed significantly higher number of small intestinal tumors compared with the untreated groups receiving the same diets ($P < 0.001$ for both comparisons). Hence, PhIP treatment increased intestinal tumorigenesis above the spontaneous level of tumors in the *Min*/+ mice, as shown previously [25–27, 33].

In mice treated with PhIP, a 45% fat diet given throughout life gave a significantly higher number of small intestinal tumors compared with exposure to a 45% fat diet during

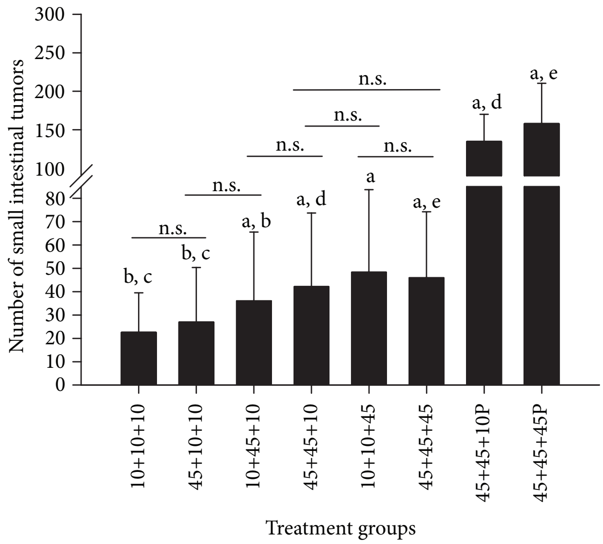


Figure 9: The number of small intestinal tumors for pooled male and female *Min*/+ mice (mean ± SD). Two separate experimental groups receiving a 45% fat diet during *in utero* and nursing period or throughout life were injected with PhIP (marked P). The experimental groups are as explained in the legend to Figure 1. $n = 44–65$. [a]Significantly different from the negative control group given a 10% fat diet throughout life. [b]Significantly different from the group given a 45% fat diet throughout life. [c]Significantly different from the group given a 45% fat diet *in utero* and during nursing. [d]Significantly different with PhIP compared with no PhIP exposure in the groups given a 45% fat diet during *in utero* and nursing period. [e]Significantly different with PhIP compared with no PhIP exposure in the groups given a 45% fat diet throughout life. n.s. = not significantly different.

in utero and nursing ($P < 0.001$), whereas this effect of diet was not seen in the mice not treated with PhIP.

Small intestinal tumors from mice not treated with PhIP had diameters of 0.2–3.6 mm, whereas the tumor diameters from PhIP-treated mice were 0.2–4.5 mm. The males appeared to have larger tumors than the females ($P = 0.047$ for all mice), however, the difference was not statistically significant in most of the treatment groups, and the direction of this difference was not consistent since in some groups females had larger tumors than males. Therefore, the data are evaluated statistically for females and males together (data not shown).

In the mice exposed to a 45% fat diet *in utero* or during nursing, the differences in tumor diameter were not significantly different compared with the negative control group given a 10% fat diet. In the mice receiving a 45% fat diet during both the *in utero* and nursing periods, the tumors were larger than in the control group ($P = 0.035$), indicating a possible effect on tumor growth from this early exposure to a 45% fat diet. The 45% fat diet during both *in utero* and nursing periods also gave significantly larger tumors compared with all the other groups receiving a 45% fat diet for various periods, including a 45% fat diet as adults and throughout life ($P < 0.001$ for all comparisons). In the mice receiving a 45% fat diet during adult life or throughout life, the tumors were

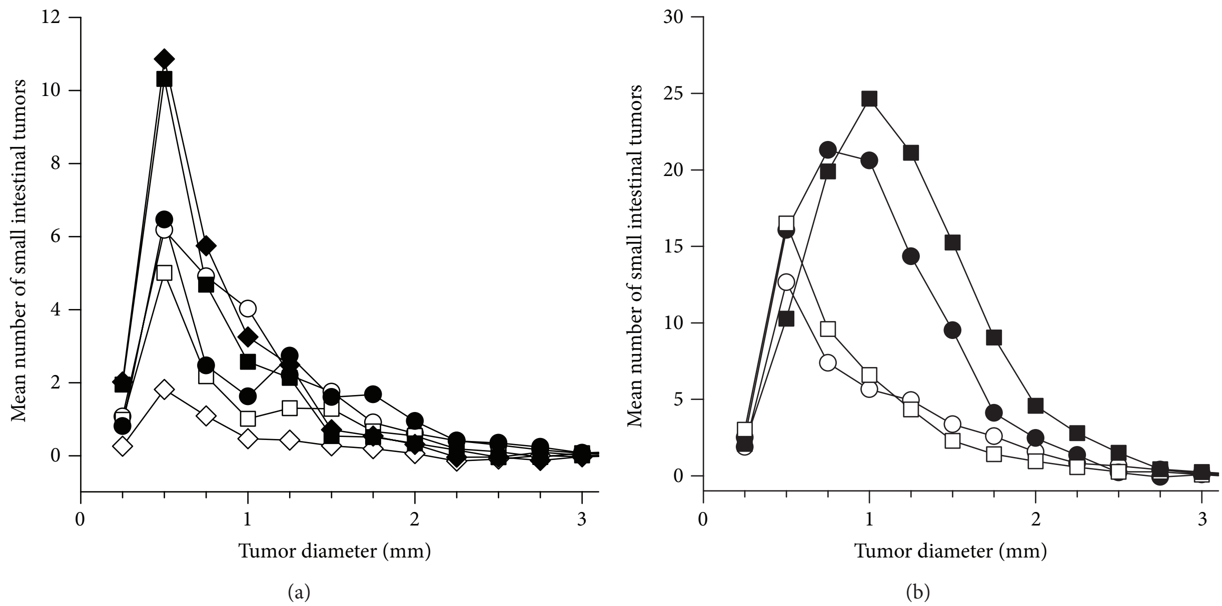


Figure 10: The net effect on tumor size of (a) a 45% fat diet, and (b) of PhIP exposure. (a) The size distribution of small intestinal tumors from untreated pooled female and male *Min*/+ mice exposed to a 45% fat diet for various periods is calculated by subtracting the mean number of tumors in the mice exposed to a 10% fat diet throughout life from the mean number of tumors in the treatment groups receiving a 45% fat diet for various periods for each tumor size class. (b) The size distribution of small intestinal tumors from pooled female and male *Min*/+ mice exposed to PhIP is calculated by subtracting the mean number of spontaneous tumors in the mice not exposed to PhIP from the mean number of tumors formed in PhIP-treated mice for each tumor size class. The intervals between the tumor size classes are 0.25 mm. The symbols for the experimental groups are as follows: in (a) 10+10+10 (○), 45+10+10 (◊), 10+45+10 (□), 45+45+10 (●), 10+10+45 (◆) 45+45+45 (■), and in (b) the dietary groups without PhIP exposure; 45+45+10 (○), 45+45+45 (□), and the same PhIP-exposed dietary groups with (●) or (■), respectively. The experimental groups are as explained in the legend to Figure 1. $n = 44$–65.

smaller compared with in the negative control mice ($P < 0.05$ for both comparisons), possibly indicating formation of new tumors. The exposure to a 45% fat diet as adults or throughout life gave significantly smaller tumors than in all the other groups exposed to a 45% fat ($P < 0.05$ for all comparisons). The exposure to a 45% fat diet throughout life did not affect the tumor size differently from a 45% fat diet only as adults.

To better illustrate the variations in size of the small intestinal tumors between the dietary groups, curves are shown of the size distribution of tumors (Figure 10(a)), calculated by subtracting the number of tumors in mice exposed to a 10% fat diet throughout life from the number of tumors in the other treatment groups receiving a 45% fat diet for various periods for the different size classes of tumors. It can be seen that the curve for exposure to a 45% fat diet both *in utero* and during nursing is higher than the control group and all other groups to the right, indicating more of the larger tumors, whereas the other treatment groups have curves below the control group for the larger tumor sizes, indicating fewer larger tumors.

PhIP increased the size of the small intestinal tumors compared with the same dietary groups without PhIP (data not shown), both when exposed to a 45% fat diet *in utero* and during nursing ($P < 0.05$) and when exposed throughout life ($P < 0.05$). The PhIP-exposed group given a 45% fat diet throughout life had larger tumors than the PhIP-exposed group given a 45% fat diet *in utero* and during nursing ($P < 0.05$).

The size of the PhIP-induced tumors was illustrated by curves of size distributions of PhIP-induced tumor populations, which were calculated by subtracting the number of tumors in the corresponding dietary group not exposed to PhIP from the number of tumors in the PhIP-treated groups for the difference tumor size classes (Figure 10(b)). It can be seen that the curves for the PhIP-exposed groups are to the right of the curves for the corresponding dietary groups not exposed to PhIP, illustrating larger tumors after PhIP exposure.

3.17. Colonic Tumors. Not all of the mice had colonic tumors, regardless of treatment, consistent with results found in our previous experiments with *Min*/+ mice [25–27, 33, 34]. There was a higher incidence of colonic tumors in males compared with females in the dietary groups given a 45% fat diet only as adults ($P = 0.031$) and in PhIP-treated mice after exposure during *in utero* and nursing ($P = 0.030$). The only significant difference between the various dietary combinations was a higher incidence of colonic tumors in the female mice exposed to a 45% fat diet only *in utero* versus only as adults ($P = 0.038$). A higher incidence of colonic tumors was observed with PhIP in the group given a 45% fat diet throughout life, in females separately ($P = 0.016$) and in both genders combined ($P = 0.018$), compared with no PhIP-treatment.

The number of colonic tumors was significantly higher in males compared with females for all mice ($P < 0.001$), and in the treatment groups exposed to a 45% fat diet *in utero* and during nursing ($P = 0.023$) and throughout life ($P = 0.035$), hence the data are evaluated separately for females and males (data not shown). Probably because of the very low number of colonic tumors, statistical significance was not reached for any of the differences between the dietary groups. However, except for the comparison with a 45% fat diet *in utero* in females, the number of colonic tumors after the 45% fat diet *in utero* and during nursing was higher than in all the other groups exposed to a 45% fat diet for various periods and not treated with PhIP, in both females and males (data not shown). PhIP significantly increased the number of colonic tumors, in both the dietary group given a 45% fat diet *in utero* and during nursing ($P = 0.006$) and throughout life ($P = 0.008$).

Colonic tumors had diameters of 1.0–5.4 mm in mice from the dietary groups not exposed to PhIP, while the diameter in the PhIP-treated groups ranged from 0.9–6.0 mm. There were no significant differences between the genders or between the various dietary groups in colonic tumor size, and there was no statistically significant effect of PhIP on colonic tumor diameter (data not shown).

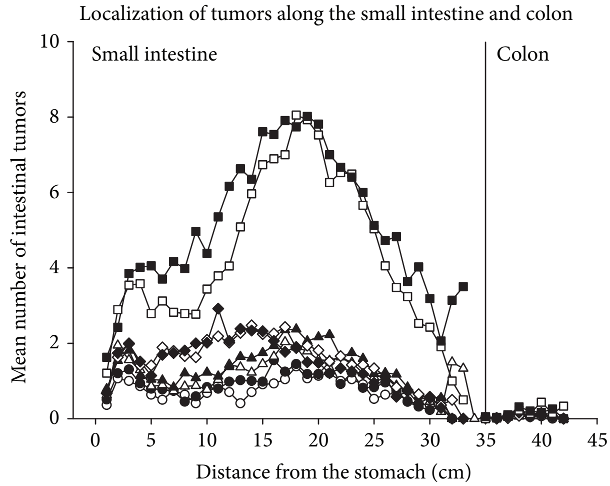


Figure 11: Localization of tumors along the small intestine and colon for pooled female and male *Min*/+ mice; 10+10+10 (○), 45+10+10 (●), 10+45+10 (△), 45+45+10 (▲), 10+10+45 (◊) and 45+45+45 (◆), and the PhIP-exposed groups; 45+45+10 (□), and 45+45+45 (■). The tumor position is given as distance from the stomach measured in cm. The experimental groups are as explained in the legend to Figure 1. $n = 44–65$.

3.18. Localization of Tumors along the Small Intestine and Colon. The majority of tumors were localized in the distal two-thirds (in the middle and distal parts) of the small intestine in the mice that were exposed to a 10% fat diet throughout life, a 45% fat diet *in utero*, during nursing, or during both *in utero* and nursing (Figure 11), as has usually been found in our previous experiments with *Min*/+ mice [26, 27, 33, 34]. The mice that were given a 45% fat diet as adults or throughout life had additional tumors in the proximal part of the small intestine (Figure 11). The PhIP-treated mice had most of the tumors localized in the distal two-thirds of the small intestine and also quite high numbers in the proximal part of the small intestine. This unusual additional increase in tumors proximally in the small intestine was also observed in a previous experiment with genetically-induced obese mice, that is, in *Min*/+ mice crossed with *ob/ob* mice, who gets obese when homozygous mutated. Also in the previous experiment as in the present study, the tumor number was increased further in this area of the small intestine when the mice were given a 45% fat diet (another brand in the previous experiment than in the present experiment) (Ngo et al., 2014; unpublished results).

The few colonic tumors present were localized mainly in the middle to distal parts of the colon (Figure 11), as seen in previous experiments with *Min*/+ mice [26, 27, 33, 34].

3.19. Absolute and Relative Liver and Spleen Weights. To examine if the obesogenic treatment in various periods of life could affect organ weights, in addition to body weight, the absolute and relative weights of liver and spleen were measured at termination of the *Min*/+ mice at 11 weeks of age, and of the wild-type mice at 23 weeks of age. In the *Min*/+ mice (Table 1), the males had higher absolute liver weight than the females, based on all mice, and in each dietary treatment group separately ($P < 0.001$ for all comparisons). The only significant differences in absolute liver weight found between the dietary treatment groups were that the male mice given a 45% fat diet during both *in utero* and nursing periods had significantly higher absolute liver weight than the mice given a 45% fat diet only as adults ($P = 0.007$) or throughout life ($P = 0.018$). In the *Min*/+ males, exposure to a 45% fat diet *in utero* and during nursing without PhIP gave a higher absolute liver weight than the same diet with PhIP exposure ($P = 0.023$). None of these differences between the dietary treatment groups were seen in females.

The relative liver weight in % was not significantly different between the males and females. Compared with the negative control group given a 10% fat diet throughout life, none of the other dietary treatment groups differed in relative liver weight either in female or male *Min*/+ mice. In the males, exposure to a 45% fat diet only *in utero*, only during nursing, or *in utero* and during nursing, gave a higher relative liver weight than a 45% fat diet throughout life ($P < 0.001$, $P = 0.045$ and $P < 0.001$, resp.). Exposure to a 45% fat diet throughout life with PhIP gave a higher relative liver weight than the same diet without PhIP exposure in the *Min*/+ males ($P < 0.001$) and females ($P = 0.005$). None of the other comparisons of relative liver weight between dietary groups reached significance in the females.

The absolute spleen weight was not significantly different between the *Min*/+ females and males. The male *Min*/+ mice given a 45% fat diet *in utero* and during nursing had significantly higher absolute spleen weight compared with the negative control mice given a 10% fat diet throughout life ($P = 0.003$), mice given a 45% fat diet only *in utero* ($P < 0.001$), mice given a 45% fat diet as adults ($P = 0.004$) and mice given a 45% fat diet throughout life ($P = 0.005$). In the *Min*/+ males, exposure to a 45% fat diet throughout life with PhIP gave a higher absolute spleen weight than the same

Table 1: Effects of exposure to a 45% fat diet during various periods of life on absolute liver weight (ALW), relative liver weight (RLW), absolute spleen weight (ASW), and relative spleen weight (RSW) in female and male *Min*/+ mice terminated at 11 weeks of age (mean of individual mice in the group ± SD).

Experimental group	n	BW (g)	ALW (g)	RLW (%)	ASW (g)	RSW (%)
Min/+, females						
10 + 10 + 10	22	19.4 ± 1.6	0.74 ± 0.18	3.81 ± 0.74	0.12 ± 0.03	0.65 ± 0.21
45 + 10 + 10	17	20.1 ± 1.8	0.82 ± 0.16	4.08 ± 0.58	0.12 ± 0.05	0.60 ± 0.22
10 + 45 + 10	27	21.4 ± 1.8	0.82 ± 0.11	3.84 ± 0.55	0.15 ± 0.09	0.69 ± 0.42
45 + 45 + 10	18	20.1 ± 1.7	0.82 ± 0.10	4.10 ± 0.46	0.17 ± 0.11	0.86 ± 0.60[a,b]
10 + 10 + 45	34	20.9 ± 2.6	0.75 ± 0.13	3.64 ± 0.52	0.12 ± 0.05	0.58 ± 0.22[a]
45 + 45 + 45	22	23.2 ± 2.6	0.84 ± 0.14	3.66 ± 0.47[a]	0.13 ± 0.05[a]	0.55 ± 0.22[b,c]
45 + 45 + 10 PhIP	22	20.6 ± 2.2	0.86 ± 0.10	4.23 ± 0.54	0.21 ± 0.11	1.00 ± 0.55
45 + 45 + 45 PhIP	15	19.5 ± 2.9	0.83 ± 0.14	4.35 ± 0.84[a]	0.23 ± 0.11[a]	1.23 ± 0.68[c]
Min/+, males						
10 + 10 + 10	17	27.4 ± 2.6	1.10 ± 0.19	4.01 ± 0.55	0.12 ± 0.05[a]	0.45 ± 0.21[a]
45 + 10 + 10	29	27.8 ± 2.6	1.16 ± 0.16	4.16 ± 0.36[a]	0.13 ± 0.07[b]	0.46 ± 0.26[b]
10 + 45 + 10	30	28.3 ± 2.8	1.14 ± 0.21	3.99 ± 0.55[b]	0.16 ± 0.08	0.59 ± 0.31
45 + 45 + 10	19	28.8 ± 2.2	1.22 ± 0.21[a,b,c]	4.23 ± 0.67[c]	0.21 ± 0.13[a,b,c,d]	0.75 ± 0.47[a,b,c,d]
10 + 10 + 45	25	28.0 ± 3.2	1.05 ± 0.15[a]	3.78 ± 0.56	0.13 ± 0.06[c]	0.48 ± 0.20[c]
45 + 45 + 45	29	29.9 ± 3.2	1.07 ± 0.15[b]	3.58 ± 0.45[a,b,c,d]	0.14 ± 0.06[d,e]	0.47 ± 0.22[d,e]
45 + 45 + 10 PhIP	27	25.3 ± 3.0	1.09 ± 0.14[c]	4.34 ± 0.49	0.23 ± 0.11	0.94 ± 0.52
45 + 45 + 45 PhIP	29	26.5 ± 5.6	1.09 ± 0.20	4.20 ± 0.84[d]	0.26 ± 0.09[e]	1.00 ± 0.39[e]

Relative liver weight (RLW) (%) = absolute liver weight (ALW)/body weight (BW) × 100, relative spleen weight (RSW) (%) = absolute spleen weight (ASW)/BW × 100. g = gram.
[a–e]Dietary treatment groups within each gender with similar letters are significantly different.

diet without PhIP exposure ($P < 0.001$). This comparison was also significant in females ($P = 0.013$), whereas none of the other comparisons of absolute spleen weight between the dietary groups reached significance in the females.

The relative spleen weight in % was significantly higher in female than in male *Min*/+ mice, based on all mice ($P = 0.002$), but this gender difference did not reach significance in any of the dietary treatment groups separately. The *Min*/+ mice given a 45% fat diet *in utero* and during nursing had borderline or significantly higher relative spleen weight compared with the control male mice given a 10% fat diet throughout life ($P = 0.051$), male mice given a 45% fat diet *in utero* ($P = 0.025$), a 45% fat diet as adults ($P = 0.049$ in males and $P = 0.031$ in females), and a 45% fat diet throughout life ($P = 0.028$ in both males and females). The relative spleen weight in *Min*/+ mice given a 45% fat diet throughout life with PhIP was significantly higher than the same dietary group without PhIP, in both females and males ($P < 0.001$ for both comparisons).

Also in the wild-type mice (Table 2), the males had higher absolute liver weight than the females, based on all mice ($P < 0.001$), and in each dietary treatment group separately ($P < 0.001$ in all treatment groups, except for the group given a 45% fat diet only during nursing where $P = 0.019$). The only significant differences in absolute liver weight found between the dietary treatment groups in the wild-type mice were that the male mice given a 45% fat diet throughout life had significantly higher absolute liver weight than the control mice given a 10% fat diet throughout life ($P = 0.028$) and the mice given a 45% fat diet only during nursing ($P = 0.027$), whereas these differences were not seen in females. PhIP treatment did not affect the absolute liver weight in the wild-type mice.

The relative liver weight in % was also significantly higher in males than in females, based on all mice ($P < 0.001$), and also in the individual dietary treatment groups of mice given a 45% fat diet *in utero* ($P = 0.017$), as adults ($P = 0.024$), or throughout life ($P < 0.001$). No significant differences were found in relative liver weight between any of the dietary treatment groups in male wild-type mice. In females, the relative liver weight was significantly higher in mice in the negative control group given a 10% fat diet throughout life ($P < 0.001$), a 45% fat diet *in utero* ($P = 0.003$), a 45% fat diet during nursing ($P < 0.001$), or a 45% diet *in utero* and during nursing ($P < 0.001$), compared with the mice given a 45% diet throughout life. In females, the relative liver weight was also significantly higher in mice in the negative control group given a 10% fat diet throughout life ($P < 0.030$), a 45% fat diet during nursing ($P = 0.008$), or a 45% fat diet *in utero* and during nursing ($P = 0.048$), compared with the mice given a 45% diet as adults. PhIP treatment did not affect the relative liver weight in wild-type mice.

There were no significant differences in absolute spleen weight between the genders among the wild-type mice. The only significant difference between the dietary treatment groups was a higher absolute spleen weight in female wild-type mice given a 45% fat diet during nursing compared with as adults ($P = 0.004$), which was not seen in males. PhIP treatment did not affect the absolute spleen weight in wild-type mice.

Table 2: Effects of exposure to a 45% fat diet during various periods of life on absolute liver weight (ALW), relative liver weight (RLW), absolute spleen weight (ASW), and relative spleen weight (RSW) in female and male wild-type mice terminated at 23 weeks of age (mean of individual mice in the group ± SD).

Experimental group	n	BW (g)	ALW (g)	RLW (%)	ASW (g)	RSW (%)
+/+, females						
10 + 10 + 10	26	25.9 ± 3.3	1.03 ± 0.34	3.91 ± 0.87[a,e]	0.12 ± 0.03	0.45 ± 0.13[a,b]
45 + 10 + 10	24	26.8 ± 4.2	1.03 ± 0.32	3.79 ± 0.85[b]	0.11 ± 0.03	0.41 ± 0.12
10 + 45 + 10	21	28.0 ± 3.9	1.15 ± 0.38	4.04 ± 0.89[c,f]	0.14 ± 0.09[a]	0.50 ± 0.37[c,d]
45 + 45 + 10	31	27.6 ± 3.9	1.08 ± 0.35	3.84 ± 0.83[d,g]	0.11 ± 0.03	0.42 ± 0.14
10 + 10 + 45	26	31.3 ± 6.2	1.02 ± 0.22	3.27 ± 0.49[e,f,g]	0.10 ± 0.02[a]	0.33 ± 0.10[a,c]
45 + 45 + 45	31	34.3 ± 4.0	1.04 ± 0.23	3.02 ± 0.51[a,b,c,d]	0.11 ± 0.02	0.34 ± 0.09[b,d]
45 + 45 + 10 PhIP	21	27.0 ± 3.6	1.11 ± 0.34	4.06 ± 0.87	0.12 ± 0.03	0.43 ± 0.13
45 + 45 + 45 PhIP	21	33.9 ± 7.5	1.05 ± 0.32	3.09 ± 0.66	0.11 ± 0.02	0.34 ± 0.11
+/+, males						
10 + 10 + 10	25	35.0 ± 5.1	1.43 ± 0.41[a]	4.02 ± 0.75	0.11 ± 0.02	0.34 ± 0.11
45 + 10 + 10	36	36.0 ± 4.3	1.54 ± 0.26	4.28 ± 0.53	0.11 ± 0.02	0.30 ± 0.07
10 + 45 + 10	24	37.2 ± 4.2	1.42 ± 0.24[b]	3.81 ± 0.47	0.11 ± 0.02	0.30 ± 0.07
45 + 45 + 10	27	36.4 ± 5.6	1.51 ± 0.37	4.18 ± 0.90	0.10 ± 0.03	0.29 ± 0.09
10 + 10 + 45	27	40.5 ± 7.5	1.54 ± 0.53	3.75 ± 0.83	0.10 ± 0.02	0.25 ± 0.07
45 + 45 + 45	46	42.9 ± 5.8	1.73 ± 0.59[a,b]	3.95 ± 0.98	0.12 ± 0.02	0.28 ± 0.08
45 + 45 + 10 PhIP	25	38.5 ± 4.1	1.49 ± 0.30	3.84 ± 0.47	0.12 ± 0.04	0.32 ± 0.15
45 + 45 + 45 PhIP	28	44.6 ± 5.0	1.70 ± 0.47	3.76 ± 0.74	0.11 ± 0.02	0.24 ± 0.05

Relative liver weight (RLW) (%) = absolute liver weight (ALW)/body weight (BW) × 100, relative spleen weight (RSW) (%) = absolute spleen weight (ASW)/BW × 100. g = gram.
[a–f]Dietary treatment groups within each gender with similar letters are significantly different.

The relative spleen weight in % was significantly higher in female than in male wild-type mice also, based on all mice ($P < 0.001$), and this difference reached significance in all of the dietary treatment groups separately, except for the group given a 45% fat diet throughout life (P values varied from < 0.001 to 0.028). No significant differences were found in relative spleen weight between any of the dietary treatment groups in male mice. Female mice in the negative control group given a 10% fat diet throughout life had significantly higher relative spleen weight compared with the mice given a 45% fat diet as adults, and compared with mice given a 45% fat diet throughout life ($P = 0.020$ for both comparisons). Also female mice given a 45% fat diet only during nursing had significantly higher relative spleen weight compared with the mice given a 45% fat diet as adults, and compared with mice given a 45% fat diet throughout life ($P < 0.001$ for both comparisons). PhIP treatment did not affect the relative spleen weight in wild-type mice.

3.20. Serum Leptin Levels. There were no significant differences in levels of the serum hormone leptin obtained at termination between the genders of mice or between any of the dietary treatment groups (Figure 12). The only significant difference found was that the wild-type mice had significantly higher levels of leptin than the *Min*/+ mice. This was found based on all mice ($P < 0.001$), and in the dietary group of mice given a 45% fat diet both *in utero* and during nursing ($P < 0.001$).

4. Discussion

The intake of feed per gram body weight in the dams was significantly lower for the 45% fat diet than the 10% fat diet during the second and third week of pregnancy (Figure 2(a)). This was most likely caused by a lower feed intake and/or increased body weight (Figure 4) with the 45% diet, and not by different number of pups per litter, since both dietary groups of dams gave birth to similar mean number of pups per litter.

The mice given a 45% fat diet either as adults (for 8 weeks) or throughout life (for 11 weeks), with or without PhIP, had significantly lower feed intake per gram body weight per week than the other dietary groups receiving a 10% fat diet throughout life (for 11 weeks or 23 weeks), or a 45% fat diet for shorter time, that is, only *in utero* (for 3 weeks), only during nursing (for 3 weeks) or during *in utero* and nursing (for 6 weeks), with or without PhIP (Figure 3). Apparently, there is an adjustment of feed intake, that is, calorie intake, over time, leading to lower intake of the 45% fat diet compared with the 10% fat diet or the 45% fat diet for shorter time. This difference in feed intake between long exposure versus no/short exposure to a 45% fat diet varied with the individual diets and in the individual weeks but reached approximately 20–30% from weeks 5-6 to week 11 in both *Min*/+ and wild-type female and male mice, and in most of the weeks in both female and male wild-type mice at weeks 12 to 23. The 45% fat diet has 4.73 kcal/g, whereas the 10% fat diet has 3.85 kcal/g, that is, the 45% fat diet contains 22.9% more kcal per gram

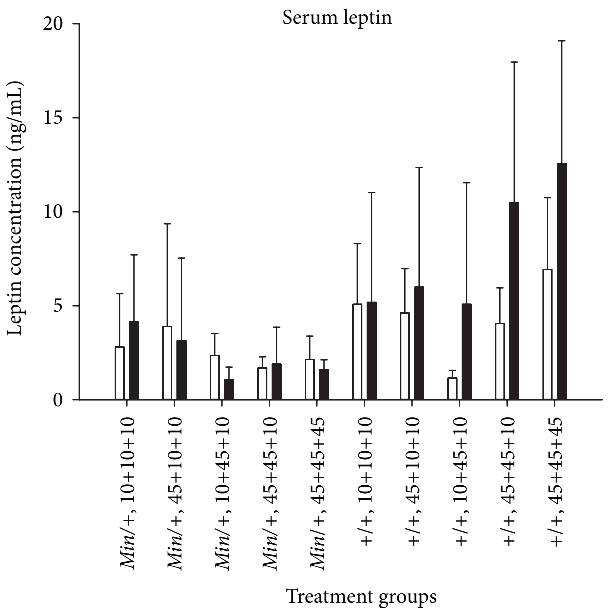


Figure 12: The concentration of leptin in serum at termination was measured in both *Min*/+ and wild-type (+/+) mice of both genders from all the dietary groups except 10+10+45 (see explanation in the legend to Figure 1), not treated with PhIP ($n = 6$). Females (white columns), males (black columns).

diet. Therefore, it appears that the mice adjusted their intake of feed to approximately the same level of kcal, and the effects observed in this experiment are likely caused by the dietary fat as such more than by just the excess calories.

The body weights of the dams during weeks 1 and 2 of pregnancy were significantly higher for the dams on a 45% fat diet compared with dams on a 10% fat diet, although the differences were small, being 3.3% at week 1 and 7.2% at week 2 (Figure 4). At the end of the pregnancy, the difference was only 2.0% and not significant. Since the dams had increased body weight after the 45% fat diet, it is not possible to separate the effect on the offspring *in utero* of increased body weight (obesity) in the dams from the effects of the 45% fat diet as such.

The 10% fat and 45% fat diets both have 20 kcal% protein and the same content of vitamins and minerals. The 10% and 45% fat diets are matched on sucrose, that is, both contain 17% sucrose as percentage of the calories. However, there are differences in other carbohydrates, that is, the 45% fat diet contains less corn starch (291 kcal) and more maltodextrin 10 (a partially hydrolyzed form of corn starch, 400 kcal), than the 10% fat diet (1808.8 kcal corn starch and 300 kcal maltodextrin 10), in total 35 kcal% comes from carbohydrate in the 45% fat diet compared with 70 kcal% in the 10% fat diet. Regarding the content of fat, both diets have the same kcal% from soybean oil (225 kcal), but the 45% fat diet has almost 9 times the content of lard (1598 kcal) as in the 10% fat diet (180 kcal), and in total 45 kcal% comes from fat compared with 10 kcal%.

Since the mice apparently adjust their feed intake over time to approximately the same percentage of calories, the effects observed in this study may be caused by other difference in the diets than calories, that is, by the content of carbohydrates other than sucrose or by the lard (type of fat).

In human studies, various indicators of obesity, such as BMI, waist circumference and waist-to-hip ratio, waist-height-ratio or percentage of body fat, have been found to be more or less strongly associated with study end points [36]. In this work, we have evaluated obesity in three different ways; as body weight development using AUC calculated for a specified time period, as body weight at a specific age and as terminal BMI.

When evaluated as AUC from age 3-4 days to 11 weeks, there was an obesogenic effect of an early exposure to a 45% fat diet *in utero* and during nursing, or only during nursing, showing that the intrauterine and nursing period is a susceptible window of exposure to a high fat diet for later development of obesity as adults (Figures 6(a)–6(d)). However, this effect in AUC from day 3-4 to week 11 of an early exposure to a 45% fat diet was no longer present when evaluated as AUC for the age of 12 to 23 weeks in the wild-type mice (Figures 6(e) and 6(f)), indicating that this effect was transient. Similarly, the observed effects of an early exposure to a 45% fat diet during *in utero* and nursing, or only during nursing, on body weight at age 11 weeks were no longer present when the wild-type mice had reached the age of 23 weeks. As opposed to body weight development as AUC from day 3-4 to week 11 and body weight at 11 weeks, the end point terminal BMI at 11 weeks did not demonstrate the sensitive period for obesity early in life from exposure to a 45% fat diet in the *Min*/+ mice. Likewise, the end point terminal BMI at 23 weeks did not demonstrate in the wild-type mice the sensitive period for obesity early in life from exposure to a 45% fat diet. So for this end point, BMI was not as sensitive as body weight at a specific age, and even less sensitive, compared with AUC for body weight development. AUC, which integrates the changes in body weight over a longer period of time, was the best end point in this experiment. BMI was also found to be the least sensitive and specific of several obesity-related predictors of metabolic syndrome in a human population [36].

In addition to affecting the body weight of the mice, the early exposure to a 45% fat diet during both *in utero* and nursing periods increased the organ weights compared with the much longer exposure to a 45% fat diet later in life, that is, as adults or throughout life. This was observed for the relative liver weight compared with a 45% fat diet throughout life in male *Min*/+ mice (Table 1), and compared with a 45% fat diet as adults or throughout life in female wild-type mice (Table 2). Also the relative spleen weight after exposure to a 45% fat diet during both *in utero* and nursing periods was increased compared with a 45% fat diet as adults or throughout life in both female and male *Min*/+ mice (Table 1). The absolute liver weight and the absolute spleen weight were also increased by the exposure to a 45% fat diet during both *in utero* and nursing periods compared with a 45% fat diet as adults or throughout life in male *Min*/+ mice (Table 1).

Maternal obesity and developmental programming of metabolic disorders in the offspring have been studied extensively in animal models [37–40]. Animal studies indicate that both the fetal period and the postnatal period may be critical windows for development, and hence, alterations in the nutrition during these periods could induce metabolic programming effects, which may be manifested as pathological conditions later in life. Several physiological and metabolic mechanisms are not fully matured at birth and continue maturation in the immediate postnatal period, for example, neurons and pancreatic islets continue to develop after birth in rodents [41]. Many studies have exposed female animals for a high fat diet early in life; during pregnancy or during lactation, or during both periods, and found long-term consequences of metabolic and endocrine pathophysiology in one or both genders of the offspring as adults, both in mice [42–44] and rats [45–48]. Interestingly, prenatal stress seems to have similar effects as a high fat diet for increased susceptibility to diet-induced obesity in the offspring [47]. Relevant data also come from human studies. For instance, it was shown that high pregnancy weight gain was associated with increased body weight of the offspring in childhood, and that this effect was only partially mediated through higher birth weight [49]. However, this question is still not resolved in humans, since in another study, maternal overweight/obesity was associated with early deceleration of growth, seen as less weight gain, less length growth and less fat mass at three months of age [50]. A systematic review of maternal and paternal body mass index and offspring obesity concluded that there was only limited evidence to support the fetal overnutrition hypothesis in humans [51].

However, we have compared the outcome of exposure to a 45% fat diet among several specific periods of life. For body weight measured as AUC from day 3-4 to week 11 and as body weight at age 11 weeks, and for the number of small intestinal tumors, exposure only *in utero* had less effect that exposure during nursing, or during both the *in utero* and nursing periods. The diameter of small intestinal tumors was also increased after exposure during both the *in utero* and nursing periods. These results point to exposure via the milk during the nursing period as more important than exposure *in utero* for these effects. Another study in mice found that a high fat diet limited to the lactation period caused diet-induced obesity in the male offspring [44]. Also, a study in rats showed that maternal high fat diet during the nursing period had greater influence on the offspring's metabolic phenotype and body weight than prenatal (*in utero*) high fat diet [52]. For obvious reasons, studies in humans are not able to compare obesogenic exposure in separated periods of life, such as during pregnancy and the lactation period. However, in a case-cohort study of Danish children, it was found that infant weight and weight gain already during the first months of life were associated with obesity in childhood [53]. They did not observe any particular critical time period during infancy related to the weight gain from 2 weeks to 9 months of age; odds ratios increased from 1.27 associated with an increase of 1 weight-tertile from age 2 weeks to 1 month, and to 1.54 from 2 to 3 months of age, thereafter the odds ratio were stable until 9 months of age.

Our data stress the importance of early exposure to obesogenic conditions compared with the same exposure later in life, that is, as adults. For instance, the exposure to a 45% fat diet as adults did not increase body weight as AUC from day 3-4 to week 11 compared with the control group or any of the other exposure groups, whereas the exposure to a 45% fat diet during nursing actually gave a significantly higher AUC than exposure as adults *in Min*/+ male mice ($P = 0.011$). Also for body weight of *Min*/+ and wild-type mice at 11 weeks of age and terminal BMI for *Min*/+ mice at 11 weeks of age, the effects of a 45% fat diet as adults did not increase the values compared with exposure *in utero*, during nursing, or during both *in utero* and nursing. One could speculate if this effect was only due to differences in length of exposure to a 45% fat diet, rather that exposure in a particular period. However, this is not the case, since exposure as adults is from weaning at age 3 weeks until age 11 weeks for *Min*/+ mice, and from weaning at age 3 weeks until age 23 weeks for wild-type mice, that is, in 8 and 20 weeks, respectively. Exposure throughout life is from conception to termination at 11 weeks for *Min*/+ mice, and from conception to termination at 23 weeks for wild-type mice, that is, 14 and 26 weeks, respectively. In comparison, the exposure to a 45% fat diet *in utero* was for 3 weeks, the exposure during nursing was for 3 weeks, and the exposure both *in utero* and during nursing was then for 6 weeks, all much shorter than the exposures to a 45% fat diet as adults and throughout life.

As opposed to the situation at 11 weeks, when comparing body weight after exposure as adults with the earlier exposure periods using AUC for body weight, body weight at 23 weeks or terminal BMI at 23 weeks in wild-type mice, the adult exposures increase these parameters compared with exposure *in utero*, during nursing, or both *in utero* and during nursing, indicating that the importance of early exposure has disappeared some time between 11 and 23 weeks of age. This early exposure effect seen at 11 weeks, but not at 23 weeks, is not caused by a difference between *Min*/+ mice (terminated at 11 weeks) and wild-type mice (terminated at 23 weeks), since both genotypes are implicated in these results at 11 weeks.

Maternal obesity may have consequences for production and secretion of adipokines from the adipose tissues, such as leptin. Leptin has been shown to be important for placental function and maternal-fetal exchange processes regulating growth and development, and in later stages of pregnancy central leptin resistance occurs to allow increased nutrient availability for the fetus [54]. Disruption of signaling capacity of leptin associated with obesity is a potential risk factor leading to pregnancy complications as a result of fuel partitioning *in utero*.

The only significant difference in serum leptin levels measured at termination in this study was that the *Min*/+ mice had significantly lower levels of leptin than the wild-type mice (Figure 12). At the same time, the body weight as AUC from day 3-4 to week 11 (Figure 6) and the body weight at week 11 were lower in *Min*/+ mice (Figure 5(a)) than in wild-type mice (Figure 5(b)). Therefore, in this experiment higher leptin levels were associated with increased body weight (in wild-type mice), whereas lower levels of leptin were associated with lower body weight (in *Min*/+ mice). The wild-type mice results are more similar to the situation in humans where obesity is associated with elevated levels of leptin, representing a form of leptin resistance [55, 56], as opposed to the *ob/ob* mouse model where the lack of leptin is associated with extreme obesity (see [30, 31], Ngo et al., 2014; unpublished results).

Alterations in nutrition, such as feeding a high fat diet, during critical periods of prenatal or postnatal development may induce permanent changes in the responsiveness of hypothalamic neurons to hormone signals regulating energy homeostasis and feeding, leading to increase in food intake, preference for fatty food, hyperlipidemia and higher body weight, thereby affecting the chances of becoming obese later in life [57–59]. Leptin and insulin are likely hormonal mediators for the environmental nutrient sensing system that controls feeding. Data implicate a postnatal leptin surge to be an important trophic factor for the development of hypothalamic feeding circuits and is critical for normal energy balance and hypothalamic regulation of feeding later in life [59]. Data also show that changes in insulin levels, specifically hyperinsulinemia, during pregnancy could induce alterations in hypothalamic organization that may affect metabolism of the offspring later in life [59].

The *Min*/+ mice (Figure 7(a)) had significantly higher nonfasted blood glucose levels than the wild-type mice (Figure 7(b)) at 6 weeks ($P < 0.001$), and also a larger AUC in GTT after being fasted (Figure 8). Since the feed intake in this experiment was recorded per litter, which consisted of both *Min*/+ and wild-type mice, it is not known whether there was a difference in feed intake between *Min*/+ and wild-type mice that could explain their differences in blood glucose levels. However, this is not likely, since our previous experiment found similar feed intake in *Min*/+ and wild-type mice measured in metabolic cages (Ngo et al., 2014; unpublished results). Also, the body weight was lower in *Min*/+ mice than in wild-type mice for body weight evaluated as AUC from day 3-4 to 11 weeks (Figure 6) and as body weight at 11 weeks (Figure 5). However, an alternative explanation for the difference in blood glucose levels may be that APC is involved in regulation of epithelial glucose transport in the intestines, since *Min*/+ mice had increased activity of the electrogenic glucose carrier (SGLT1) compared with wild-type mice [60]. APC is a component of the Wnt signaling pathway [19, 20]. Other intriguing possibilities of a relationship between APC and blood glucose levels come from data showing that the Wnt signaling pathway, which is as an important modulator of adipocyte differentiation [61, 62], also influences endocrine pancreas development and modulates mature β-cell functions, including insulin secretion, survival and proliferation, and thereby may be involved in the pathogenesis of diabetes [63]. Components of the Wnt signaling pathway may also be involved in determining susceptibility to diet-induced obesity [64].

Based on all values from *Min*/+ mice at 6 and 11 weeks, the PhIP-treated mice had higher blood glucose levels than mice not treated with PhIP ($P = 0.004$) (Figure 7(a)), which was also observed previously (Ngo et al., 2014; unpublished results), whereas this effect of PhIP was not significant for the wild-type mice at weeks 6 and 23 (Figure 7(b)). Blood glucose AUC in GTT was also higher in PhIP-exposed mice compared with mice not given PhIP after exposure to a 45% fat diet throughout life ($P < 0.001$), but not after exposure to a 45% fat diet *in utero* and during nursing (Figure 8). Therefore, at one or several conditions favoring intestinal tumorigenesis, that is, *Min*/+ mutation, exposure to the carcinogen PhIP and a 45% fat diet, the blood glucose levels were increased.

Exposure to the 45% fat diet only *in utero* did not significantly increase the number of spontaneous small intestinal tumors compared with the negative control group given a 10% fat diet throughout life (Figure 9). Exposure to a 45% fat diet only during the nursing period was significantly increased compared with the negative control group ($P < 0.05$), and exposure to a 45% fat diet during both the *in utero* and nursing periods significantly increased the tumor numbers further compared both with the negative control group ($P < 0.05$), and the 45% fat diet only *in utero* ($P < 0.05$), but not compared with only during nursing. Thus, the effect of a 45% fat diet during the nursing period is more efficient in increasing the tumor number than the exposure *in utero*. These data show a direct adverse effect on the offspring as adults from obesogenic conditions early in life. Also, if comparing the tumor results using litter instead of individual mice as the statistical unit, the main findings are essentially similar. The exceptions are that the tumor number after a 45% fat diet only during nursing was no longer significantly higher compared with a 10% fat diet throughout life, and a 45% fat diet throughout life was no longer significantly higher than a 45% fat diet *in utero* or only during nursing (data not shown).

Both exposures to a 45% fat diet in adult life or throughout life gave a significant increase in small intestinal tumors compared with the negative control group, the group given a 45% fat diet *in utero* and the group given a 45% fat diet only during nursing ($P < 0.05$ for all comparisons). Exposure to a 45% fat diet in adult life or throughout life did not significantly increase the number of small intestinal tumors compared with the early exposure during both *in utero* and nursing, indicating the importance of early life exposure for intestinal tumor development by a high fat diet. However, it is a discrepancy in these results, since it would be expected that exposure to a 45% fat diet throughout the whole life should give tumor numbers approaching the sum of tumor numbers after exposure to a 45% fat diet *in utero* and during nursing (i.e., early in life) and as adults (the rest of the life), whereas the tumor numbers in these three groups were not significantly different, that is, they were similar.

It is not known whether a 45% fat diet in these mice had an effect on tumor initiation, by causing mutation or loss of heterozygosity (LOH) in the remaining wild-type allele of the *Apc* gene, or affected promotion, that is, the growth of already initiated stem cells in the intestines, causing more tumors to reach a size detectable in the microscope at termination, or if both mechanisms were involved. These factors will affect the final tumor numbers measured at a specific time point. Lipotoxic free fatty acids from the 45% fat diet [65–67] and/or the subsequent obesity [68] may cause oxidative stress and accumulation of reactive oxygen species (ROS), which may have led to subsequent DNA damage and tumor initiation in the intestines.

Regarding exposure to a 45% fat diet early versus late in life, the effects on body weight coincide well with the effects on small intestinal tumor number, implicating an association between obesity and intestinal tumorigenesis. There was an obesogenic effect of an early exposure to a 45% fat diet *in utero* and during nursing, or only during nursing, when evaluated as AUC from age 3-4 days to 11 weeks or as body weight at 11 weeks, and there was significantly increased number of tumors after early exposure to a 45% fat diet during nursing or during both the *in utero* and nursing periods. The exposure to a 45% fat diet as adults was not able to increase body weight as AUC from day 3-4 to 11 weeks, body weight at 11 weeks or BMI at 11 weeks compared with the early exposure during both *in utero* and nursing, and similarly, a 45% fat diet as adults was not able to increase the tumor number compared with the early exposure during both *in utero* and nursing.

In mice treated with PhIP, a 45% fat diet given throughout life gave a significantly higher number of small intestinal tumors compared with exposure to a 45% fat diet during *in utero* and nursing ($P < 0.001$), whereas this dietary effect was not seen in the mice not treated with PhIP. In the PhIP-exposed *Min*/+ mice there were no differences in either AUC from day 3-4 to 11 weeks, body weight at 11 weeks or terminal BMI at 11 weeks between exposure to a 45% fat diet during *in utero* and nursing, or throughout life. This is difficult to interpret since PhIP itself decreased the body weight evaluated with all three body weight parameters, probably because of the increased tumor burden. Possibly, the weight-decreasing effect of PhIP could have counteracted the weight-increasing effect of the 45% fat diet, or the fat itself more than the body weight affected the number of PhIP-induced small intestinal tumors. In an earlier experiment, a 45% fat diet during adult life did not increase the number of PhIP-induced small intestinal tumors compared with exposure to a 10% fat diet in *Min*/+ × *ob* mice (Ngo et al., 2014; unpublished results).

The 45% fat diet during both *in utero* and nursing periods also gave significantly larger tumors compared with the negative control group and all the other groups receiving a 45% fat diet for various periods, including a 45% fat diet as adults and throughout life ($P < 0.001$ for all comparisons), indicating a possible effect on tumor growth from this early exposure to a 45% fat diet (Figure 10(a)). The opposite was seen with exposure to a 45% fat diet later in life. The exposure to a 45% fat diet as adults or throughout life gave significantly smaller tumors than in the negative control mice and all the other groups exposed to a 45% fat diet early in life ($P < 0.05$ for all comparisons), possibly indicating formation of new tumors. The exposure to a 45% fat diet throughout life did not affect the tumor size differently from a 45% fat diet only as adults.

The PhIP-induced tumors were both increased in number and significantly larger compared with the spontaneous tumors in the small intestine (Figure 10(b)). Whether the larger diameter of these tumors was due to an earlier induction, a faster growth, or a combination of both events, is not known.

The mice that were given a 45% fat diet as adults or throughout life had additional tumors in the proximal part of the small intestine, which was also seen after PhIP exposure (Figure 11). This unusual increase in tumors proximally in the small intestine, in addition to the more common distribution in the middle and distal parts of the small intestine, was also observed in a previous experiment with genetically-induced obese mice, that is, in *Min*/+ mice crossed with *ob* mice, who gets obese when homozygous mutated (Ngo et al., 2014; unpublished results).

In the previous experiment, the number of proximal tumors was especially high in the obese *ob*/*ob* mice and was further increased with another brand of a 45% fat diet. The reason for this phenomenon therefore seems to be associated with genetical or diet-induced obesity. It could be speculated whether it is caused by the increased secretion of bile acid into this small intestinal area caused by the high fat diet, as had been suggested to cause intestinal cancer [69].

In this experiment, blood glucose levels were measured and GTT was performed to study the hypothesis of disrupted blood glucose regulation as a link between obesity and intestinal tumorigenesis [28, 29]. However, based on both end points a shorter exposure to a 45% fat diet early in life, that is, *in utero*, during nursing, or both *in utero* and during nursing, was apparently not able to affect the blood glucose levels, whereas a longer exposure to a 45% fat diet as adults or throughout life did increase blood glucose. Therefore, in this experiment the exposure time to a 45% fat diet during the early periods of life was too short to affect the glucose levels, and the effects of the 45% fat diet and obesity on the intestinal tumorigenesis worked through a mechanism independent of blood glucose regulation. However, it should be noted that the only significant difference between later and early exposure was that exposure to a 45% diet as adults, and not throughout life, increased blood glucose levels compared with exposure both *in utero* and during nursing at 6 and 23 weeks in female wild-type mice separately ($P = 0.018$).

It is suggested that prenatal genetic or environmental factors may disrupt early development and produce long-term increased susceptibility of the offspring to new metabolic challenges later in life, causing various pathological conditions. However, in this study, we have shown that the exposure to obesogenic conditions early in life directly affected obesity in adults on a 10% fat diet without the need for a challenge in the form of exposure to a 45% fat diet also as adults. Similarly, the number of tumors formed spontaneously because of the inherited mutation in *Apc* was increases after early exposure to obesogenic conditions without a second dietary challenge as adults.

There is growing interest also in the developmental origins of cancer [70–72]. Also in this context, there are proposed influences of adipokines, such as leptin and adiponectin [73], and also insulin, on central mechanisms of energy balance, causing irreversible changes in hypothalamic neural interconnections leading to obesity and cancer. Another possibility is epigenetic modifications of specific genes, including tumor suppressor genes or oncogenes, and their altered expression, leading to cancer development. Not only a high fat diet, but other nutritional components may impact on developmental origin of cancer, since it was shown in rats that dietary protein type (soy protein isolate versus casein) during pregnancy had different effects on azoxymethane-induced colon tumor number and colon tissue gene expression, as well as serum IGF-I and testosterone levels in the offspring as adults [74]. It has also been shown in humans that body fatness at ages 5 and 10 years and higher adult height were associated with increased risk of distal adenoma, but not proximal or rectal adenoma, later in life, independent of adult body weight [75].

Apparently, the effect on adult body weight of exposures early in life disappeared sometime between 11 and 23 weeks of age. In spite of this observation, it would still be interesting to see if the effects on both body weight and intestinal tumorigenesis were transferred to the next generations, and if so, what would be the mechanisms for this transgenerational transfer. Even if the effects should be transient, they are present into reproductive age, and as such could affect the subsequent offspring.

It may be that the worldwide epidemic of obesity and subsequent risk of diabetes or metabolic syndrome and other illnesses may not only be a result of our own lifestyle of inadequate activity and poor diet as adults, but it may also be propagated and increased earlier in life because of unhealthy metabolic conditions *in utero*, that is, with fetal overgrowth/adiposity or undergrowth, as well as by obesogenic conditions during early childhood. Prevention, rather than treatment, is of interest.

There seems to be an opportunity to potentially break the cycle of obesity during pregnancy leading to obese children [76], if managing to make obese women lose weight and achieve a normal body weight/BMI prior to conception. It has been shown that maternal obesity increased both maternal and placental inflammation, but that this inflammation could be reduced by an increase in N-3/N-6 fatty acid ratio, which limited the adverse effects on the child of the developmental programming caused by the maternal obesity [77]. Therefore, even if obese mothers are not able to lose weight before or during pregnancy, improving their nutrition during pregnancy may affect the outcome of the metabolic disturbances on the fetus.

5. Conclusions

We have demonstrated in *Min*/+ mice that the intrauterine and nursing period is a window of susceptibility for exposure to a high fat diet for development of obesity, and also that this obesogenic exposure has direct adverse health effects, that is, increased intestinal tumorigenesis, in the offspring as adults. Disturbed blood glucose regulation does not appear to be involved in this association between obesity and intestinal tumorigenesis.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Review Article

Associations of Parental Influences with Physical Activity and Screen Time among Young Children: A Systematic Review

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Parents play a critical role in developing and shaping their children's physical activity (PA) and sedentary behaviours, particularly in the early years of life. The aim of this systematic review is to identify current literature investigating associations of parental influences with both PA and screen time in young children. This systematic review was conducted in November 2013 using 6 electronic databases covering research literature from January 1998 to November 2013. Thirty articles that met inclusion criteria were identified. These studies covered five important aspects of parenting: (1) parenting practices; (2) parents' role modelling; (3) parental perceptions of children's PA and screen viewing behaviours; (4) parental self-efficacy; and (5) general parenting style. Findings suggest that parents' encouragement and support can increase children's PA, and reducing parents' own screen time can lead to decreased child screen time. Improving parenting practices, parental self-efficacy or changing parenting style may also be promising approaches to increasing PA time and decreasing screen time of young children.

1. Introduction

Physical activity (PA) and sedentary behaviours (predominantly screen time) impact on the weight status of children [1–3]. Research evidence suggests that helping young children establish an active lifestyle can prevent them from overweight and obesity [4–7]. In the early years of life, parents play a critical role in developing and shaping their children's PA and sedentary behaviours through role modelling and creating a healthy home environment that increases PA and reduces screen time [8].

There have been several systematic reviews investigating correlates of PA and sedentary behaviours in young children [9–13]. These reviews used a social-ecologic framework [14] to summarize the correlates of PA and screen time of young children in five domains: (1) demographic and biological; (2) psychological, cognitive, and emotional; (3) behavioural attributes and skills; (4) social and cultural; and (5) physical environmental. Although parents' role modelling, parenting practices and parental perceptions of children's PA, and sedentary behaviours are part of the social and cultural domain, they have not been explicitly discussed in these reviews. General parenting style and parental self-efficacy that are also part of the social and cultural domain have not been investigated in these reviews.

In addition to parents' role modelling and parenting practices, general parenting style and parental self-efficacy also influence the development of PA and sedentary behaviours of young children, particularly in the early years of life [8]. Parenting style refers to a general pattern of parenting that provides the emotional background in which parents' behaviours are expressed and interpreted by a child [8]. It can be conceptualized as a context that moderates the influence of specific parenting practices on a child. Closely related to parenting practices and parenting style, parental self-efficacy is regarded as a parent's belief that he or she is capable of organizing and executing tasks related to parenting a child [15].

Findings from a recent systematic review [16] investigating associations between parental factors (parents' role modelling, parenting practices, and parental perceptions of importance and value of PA) and young children's PA were inconsistent, reporting that parental and family dynamics associated with children's PA are undeveloped. In particular, the review did not examine the parental influences on children's screen time (the time spent on watching TV, DVDs, or videos, using a computer and playing with an electronic game system) despite increasing research interest in investigating children's screen time and its independent association with childhood obesity. Further investigation was called for to clarify and understand specific parental influences that are associated with PA in children using comprehensive reviews of well-defined parental influences and their effects on both PA and screen time.

To fill in the knowledge gaps in this area, we aimed to update the current literature investigating parental influences and their associations with both PA and screen time in young children.

2. Methods

2.1. Search Strategy. In November 2013, a systematic search of the literature was conducted. Literature included in this review was retrieved from six electronic databases, including Medline, the Cochrane Central Register of Controlled Trials (CENTRAL), Cochrane Database for Systematic Review (CDSR), PsycINFO, EMBASE, and Web of knowledge. Research papers were limited to those written in English and published or included in databases from 1998 to November 2013. There was no restriction of study designs. Study participants in searched papers were limited to parents, father, and/or mother with young children aged ≤6 years. Parental influences included (1) parenting practices, (2) parents' role modelling (parents' own PA and screen time), (3) parental perceptions of children's PA and screen viewing behaviours, (4) parental self-efficacy, and (5) general parenting style. Children's PA included parent-reported "outdoor play" or "active play" and objectively measured PA level (e.g., accelerometer). The search strategy used for the Medline database is displayed in Table 1. A similar search strategy was used for other databases. Additional manual searches of the references of selected articles were also conducted for other relevant articles. Grey literature, such as unpublished studies and dissertations, was also included.

2.2. Study Selection. Study selection was based on predefined inclusion and exclusion criteria. The inclusion criteria were (1) individual quantitative studies that examined relationships of parental influences (covering at least one of the five aspects) with PA or screen time of young children; (2) studies with children aged ≤6 years old, or studies with a wide age range but describing the results specifically for children aged ≤6 years old; and (3) full text articles or dissertations, written in English. Studies were excluded from this review, if they were (1) pilot studies, (2) validation studies, (3) qualitative studies, (4) review papers, (5) studies that examined correlates of children's PA or screen time but did

Table 1: The search strategy used for Medline database.

Database: Ovid Medline(R) ⟨1946 to November Week 3 2013⟩ search strategy:
(1) preschool*.mp. (763123)
(2) young child*.mp. (34520)
(3) early child*.mp. (15721)
(4) toddler.mp. (1946)
(5) (1) or (2) or (3) or (4) (783324)
(6) parenting style*.mp. (762)
(7) parenting practice.mp. (26)
(8) parenting behavio*.mp. (847)
(9) parenting.mp. (14946)
(10) maternal influence*.mp. (460)
(11) parental influence*.mp. (439)
(12) parental self-efficacy.mp. (79)
(13) parental confidence.mp. (51)
(14) parental rules.mp. (61)
(15) parental attitudes.mp. (730)
(16) parental concerns.mp. (324)
(17) parent* support*.mp. (1197)
(18) parent* encouragement.mp. (80)
(19) parent* involvement.mp. (1051)
(20) parent modeling.mp. (22)
(21) (6) or (7) or (8) or (9) or (10) or (11) or (12) or (13) or (14) or (15) or (16) or (17) or (18) or (19) or (20) (18529)
(22) physical activit*.mp. (55070)
(23) total PA.mp. (264)
(24) MVPA.mp. (1001)
(25) PA.mp. (54822)
(26) VPA.mp. (3623)
(27) physical exercise.mp. (9183)
(28) outdoor play.mp. (102)
(29) active play.mp. (87)
(30) play.mp. (449998)
(31) leisure activit*.mp. (7741)
(32) (22) or (23) or (24) or (25) or (26) or (27) or (28) or (29) or (30) or (31) (569321)
(33) physical inactivity.mp. (3827)
(34) sedentary behavio*.mp. (1660)
(35) television viewing.mp. (957)
(36) TV viewing time.mp. (96)
(37) TV viewing.mp. (503)
(38) TV time.mp. (71)
(39) DVD*.mp. (951)
(40) video viewing.mp. (83)
(41) computer using.mp. (512)
(42) computer time.mp. (255)
(43) electronic game.mp. (34)
(44) screen time.mp. (449)

Table 1: Continued.

Database: Ovid Medline(R) ⟨1946 to November Week 3 2013⟩ search strategy:
(45) small-screen recreation.mp. (15)
(46) (33) or (34) or (35) or (36) or (37) or (38) or (39) or (40) or (41) or (42) or (43) or (44) or (45) (8478)
(47) (32) or (46) (573869)
(48) (5) and (21) and (47) (553)
(49) limit (48) to (English language and humans and yr = "1998–current") (483)

*The asterisk sign stands for any character(s).

not include any aspects of defined parental influences for this review, and (6) studies involving children aged >6 years.

A total of 1414 articles were identified through database searching. Duplicate articles ($n = 307$) were removed, resulting in 1107 individual articles for consideration. By screening the titles, 1062 articles were considered to be irrelevant and thus excluded. Forty-five papers including grey literature remained as a result of the initial search. The references of these remaining 45 articles were further screened manually to identify other relevant articles. Five additional articles were included. A total of 50 full texts were further assessed. After excluding 20 articles according to the criteria, 30 articles were included in the present review. The process of study selection is reported in Figure 1.

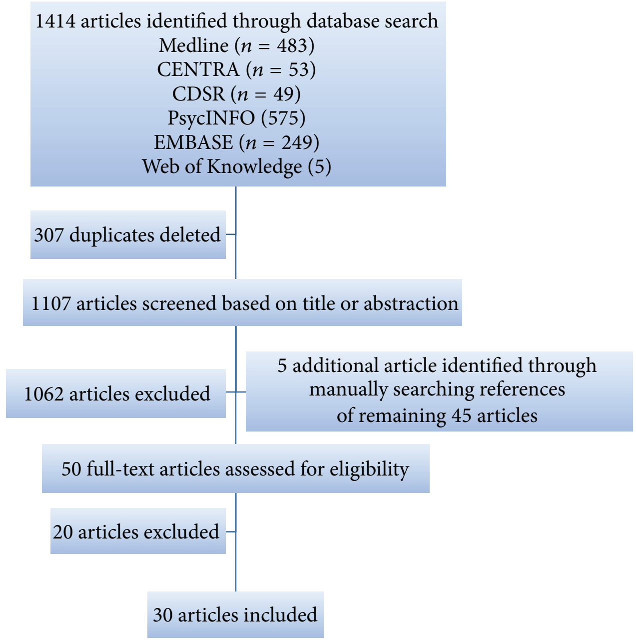

Figure 1: Flow diagram of study selection.

2.3. Assessment of Included Articles. Two reviewers (Huilan Xu and Li Ming Wen) independently screened the study titles and abstracts and then critically appraised the selected articles. Due to heterogeneity of these studies (i.e., differences in study design, study quality, and statistical analysis method), it was not possible to conduct a meta-analysis that uses statistical methods to summarize the results. Therefore, the results from this review are presented descriptively. We critically evaluated the papers using a previously established quality checklist [17] with some modifications. This quality assessment tool was originally adapted from the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [18]. For this review, the quality checklist consists of eight query items as follows: (1) was the study longitudinal or randomised controlled trail (RCT)? (2) Did the study describe the participant eligibility criteria? (3) Were the study participants randomly selected (or representative of the study population)? (4) Did the study report the sources and details of assessment for parental influences and did the instruments have acceptable reliability? (5) Did the study report the sources and details of assessments for PA and screen time and did all the methods have acceptable reliability for specific age group? (6) Did the study report a power calculation and was the study adequately powered to detect hypothesized relationships? (7) Did the study report the numbers of individuals who completed each of the different measures and did participants complete at least 80% of measures? (8) Did statistical analysis take into account the confounding? A score of "1" was assigned to "yes" to the query item, or a score of "0" was assigned. The range of score was from "0" to "8" for each paper. A paper with a score above 5 was regarded as a good quality paper.

3. Results

3.1. Description of Studies. Of the 30 articles included in this review, 14 studies were conducted in the United States, 6 in Australia, three in Canada, two in New Zealand, and one in each of Turkey, Greece, or Netherlands (Tables 2, 3, and 4). Fourteen studies [19–32] (Table 2) examined the association between parental influences and PA, with 12 studies [33–44] (Table 3) examined the association between parental influences and screen time, and four studies [45–48] (Table 4) examined associations of parental influences with both PA and screen time.

The quality scores of the papers ranged from 2 to 7 with an average score of 4.9. Most studies ($n = 24$) used cross-sectional design, with only 6 longitudinal studies having follow-up duration from 1 to 5 years. Sample sizes of these studies were reasonable based on their effect size and significance level except two studies had less than 100 participants.

3.2. Aspects and Measurement of the Parental Influences

3.2.1. Parenting Practices. The review found that various components of parenting practices regarding PA [20–23, 25–29, 31, 45, 46] or screen time [33–35, 38, 43, 45, 46, 48] were reported by 20 included studies. For child PA, parenting practices included (1) parents encouragement or support (e.g., parents participated in PA with their child, provided transportation to PA facilities, watched the child in activities,

Table 2: Association between parental influence and children's PA.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Alderman et al. (2010) USA [19]	Longitudinal	69	Baseline 4–6 Follow-up 5–15	(1) Parental PA (2) The amount of time parents report engaging in PA together with their child. (parent self-administered questionnaire)	Children's PA (parent self-administered questionnaire)	No	(1) At baseline, the relationship between parental and children's PA was moderately strong with Pearson's $r = 0.44$ ($P < 0.05$). (2) At follow-up, this relationship was weaker and no longer significant (Pearson's $r = 0.08$, $P > 0.05$). (3) The amount of time parents report engaging in PA together with their child decreased significantly over time.	4
Oliver et al. (2010) New Zealand [20]	Cross-sectional	93	2–5	(1) Parental PA rate (2) Parental PA supports/inhibitors Encouraged child to be active Parent was physically active with child Child was taken out to playground, park, beach, and so forth Restrict TV viewing	Children's PA rate (Actical accelerometers)	Children's age	**Univariable linear regression model** (1) Parental PA supports/inhibitors were not associated with children's PA rate. **Multivariable linear regression model** (2) After adjusting children's age, parental PA rate was positively associated with children's PA rate ($\beta = 0.09$, $P = 0.01$).	6
Loprinzi and Trost (2010) Australia [21]	Cross-sectional	156	2–5	(1) Parental PA (2) Parental enjoyment of PA (3) Parental support for PA (4) parental perceived importance of child PA (5) Parents' perceptions of their children's physical competence (parent self-administered questionnaire)	(1) Children's PA at home (parent self-administered questionnaire, PAEC-Q) (2) Children's PA at child care (Actigraph 7164 acclerometer)	(1) Children's age (2) Child gender	**Path analysis** (1) Parental PA and parents' perceptions of their children's physical competence were positively associated with parental support for PA ($\beta = 0.23$ and 0.18, respectively, $P < 0.05$). (2) Parental enjoyment of PA and perceived importance of child PA were not significantly associated with parental support for PA. **Home-based children's PA** (3) Parental support for PA was positively associated with home-based children's PA ($\beta = 0.16$, $P < 0.05$). (4) Parents' perceptions of their children's physical competence were directly and positively associated with home-based children's PA ($\beta = 0.2$, $P < 0.05$). **Child care MVPA** (5) Parental support for PA was not associated with children's MVPA at child care ($\beta = 0.01$, $P = 0.94$). (6) Parents' perceptions of their children's physical competence were directly and positively associated with children's MVPA at child care ($\beta = 0.28$, $P < 0.001$).	5

Table 2: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Pfeiffer et al. (2009) USA [22]	Clustered cross-sectional	331	3–5	(1) Parental VPA (2) Parental perception of their child's athletic competence (3) Family support for PA (average of responses to frequency of following items) Family encouraged PA, participated in PA with child, provided transportation to PA facilities, watched the child in activities, and told the child that PA is good (parent self-administered questionnaire)	Children's MVPA and NSA (ActiGraph accelerometers)	(1) Child gender (2) Child race (3) Child BMI z-score (4) Parent education	**Mixed model** (1) Parental perception of their child's athletic competence was positively associated with children's MVPA and NSA ($\beta = 0.39$ and 0.80, respectively, $P < 0.01$). (2) Parental VPA and family support for PA were not significantly associated with children's MVPA and NSA.	5
Zecevic et al. (2010) Canada [23]	Cross-sectional	102	3–5	(1) Parental PA (2) Family support for PA (average of responses to frequency of following items) Family encouraged PA, participated in PA with child, provided transportation to PA facilities, watched the child in activities, and told the child that PA is good (3) Parents' enjoyment of PA (4) Importance of child's PA ability (parent self-administered questionnaire)	(1) Children's PA (active play/sports) (2) Parent's perceived intensity of a child's PA (parent self-administered questionnaire)	Not reported	**Multiple logistic regression model** **Children's PA** (1) The greater parents' enjoyment of PA is, the more likely the children were to engage in the recommended amount of daily PA (PA ≥1 hour/day) (AOR 2.01, $P < 0.05$). (2) Parental PA and family support for PA were positively associated with children's PA (AOR 1.62 and 2.18, respectively, $P < 0.10$). (3) Importance of child's PA ability was not associated with children's PA. **Intensity of children's PA** (4) Parental PA and family support for PA were positively associated with children's intensity of PA (AOR 1.97 and 4.22, respectively, $P < 0.05$). (5) Parents' enjoyment of PA and importance of child's PA ability were not associated with children's PA.	3

Table 2: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Davison and Birch (2001) USA [24]	Longitudinal	185	Baseline 5 Follow-up 7	Parental PA (parent self-administered questionnaire: the level of PA: low, medium, and high)	Girl's PA (level of active) (parent self-administered questionnaire: the level of PA: low, medium, and high)	No	No associations between girls' and parents' total PA at 5 years of age.	4
Jago et al. (2005) USA [25]	Longitudinal	149	Baseline 3-4 3-year follow-up	Parental encouragement/discouragement for PA (direct observation)	(1) Children's PA (1) Heat rate monitoring (2) Direct observation with Children's Activity Rating Scale)	(1) Child BMI (2) Child ethnicity (3) Child gender	**In year 2 of the follow-up** (1) Observed children's PA was positively associated with encouragements ($r = 0.19$, $P < 0.05$) and discouragements ($r = 0.349$, $P < 0.01$) for PA. **In year 3 of the follow-up** (2) Observed children's PA was significantly associated with encouragements ($r = 0.381$, $P < 0.01$) and discouragements ($r = 0.418$, $P < 0.01$) for PA. (3) Encouragements and discouragements of PA by parents were not significant predictors of PA in regression models.	3
Beets and Foley (2008) USA [26]	Clustered cross-sectional	10694	5-6	(1) Father-child time (2) Family sports/activities together time (parent self-administered questionnaire)	Child physical activity (parent self-administered questionnaire)	(1) Child race (2) Child gender (3) Child BMI	(1) Father-child time was positively associated with child PA on weekdays ($\beta = 0.09$, $P < 0.001$) and weekends ($\beta = 0.07$, $P = 0.002$). (2) Family sports time was positively associated with child PA ($\beta = 0.27$, $P < 0.05$). (3) The effect of father-child time on child PA was mediated by family sports time. The indirect effect of father-child time on child PA was 0.03, $P < 0.001$ on weekdays, and 0.02, $P < 0.001$ on weekends.	5

Table 2: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Cleland et al. (2010) Australia [27]	Longitudinal	130	Baseline: 5-6 5-year follow-up	Parental encouragement of playing outdoors (parent self-administered questionnaire)	Child time spent outdoors (parent self-administered questionnaire)	(1) Maternal education (2) Parental marital status (3) Other	Compared to low parental encouragement, high parental encouragement was associated with more time spent outdoors on average of over 5 years for girls (234 minutes/week, 95% CI 30.1–437.8), but not for boys.	7
Dowda et al. (2011) USA [28]	Cross-sectional	411	3–5	(1) Family support Encourage child PA Play with child outdoors Provide transportation Watch child do PA or play outdoors games Tell child PA is good (2) Parent PA (3) Parent enjoys PA (4) Importance of child PA (parent self-administered questionnaire)	Child PA (MVPA created from (1) ActiGraph accelerometers (2) Direct observation (3) Parent-reported child's athletic coordination)	(1) Child gender (2) Preschool quality (3) Home PA equipment	(1) Family support was directly and significantly associated with child MVPA ($\beta = 0.28$). (2) Parent PA was indirectly associated with child's MVPA ($\beta = 0.015$, 95% CI 0.01–0.036) (mediated by family support). (3) Parent enjoys PA that was indirectly associated with child's MVPA ($\beta = 0.031$, 95% CI 0.005–0.065) (mediated by family support). (4) Importance of child participation in PA was indirectly associated with child's MVPA ($\beta =$ 0.014, 95% CI 0.001–0.034) (mediated by family support).	6

Table 2: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Hinkley et al. (2012) Australia [29]	Clustered cross-sectional	705 (weekly) 773 (weekday) 605 (weekend)	3–5	(1) Father/mother PA (2) PA interaction (3) Parent housework (4) Parent preference (child do the same activities as older siblings) (5) Parental rules restricting rough games inside (6) Parental logistic support (parent self-administered questionnaire)	Child PA (1) Weekly (2) Weekday (3) Weekend-day (ActiGraph accelerometers)	Child age Child daily sleep Number of siblings Other variables showed significance in models	**Boys:** (1) Mother's PA interaction with child was positively associated with boy's weekly PA (AOR 1.01, 95% CI 1.00–1.03). (2) Housework was negatively associated with boy's weekday PA (AOR 0.91, 95% CI 0.85–0.97). (3) Parent prefers child to do same activities as older children were negatively associated with boy's weekly (AOR 0.94, 95% CI 0.88–0.99) and weekday PA (AOR 0.92, 95% CI 0.87–0.97). (4) Rules restricting rough games inside were positively associated with boy's weekly PA (AOR 1.06, 95% CI 1.01–1.12) and weekend-day PA (AOR 1.11, 95% CI 1.02–1.20). **Girls:** (5) Paternal time in moderate PA (not total PA) was significantly associated with girl's weekly PA (AOR 1.01, 95% CI 1.00–1.02). Maternal time in vigorous PA was not significantly associated with girl's weekly, weekday, and weekend-day PA. (6) Paternal provision of logistic support was significantly associated with girl's weekend-day PA (AOR 1.03, 95% CI 1.00–1.05).	7
Ruiz et al. (2011) USA [30]	Cross-sectional	106 (80)	3–5	(1) Parent time spent in sedentary behaviour (2) Parent PA (light, moderate, and vigorous) (ActiGraph accelerometers)	(1) Child time spent in sedentary behaviour (2) Child PA (light, moderate, and vigorous) (ActiGraph accelerometers)	None for Pearson's correlation. Child age and gender for linear regression	(1) There was a strong and positive correlation between parents and their children's daily sedentary (Pearson's $r = 0.597$, $P < 0.001$), mild (Pearson's $r = 0.895$, $P < 0.0001$), and moderate (Pearson's $r = 0.739$, $P < 0.0001$) PA levels but not for vigorous PA levels (Pearson's $r = -0.07$, $P = 0.56$). (2) Parent PA was significantly associated with child's PA (β was not reported, $P < 0.0001$).	6

Table 2: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Schary et al. (2012) USA [31]	Cross-sectional	195	2–5	(1) Parental support Encouragement Playing with the child Providing transportation Watching the child participate in PA Providing information about PA (2) Dimensions of parenting style Warmth Control Irritability (3) Parenting style Authoritative Authoritarian Permissive Neglectful (parent self-administered questionnaire)	Active play (parent self-administered questionnaire with PAEC-Q)	Parent gender	(1) Parental support was positively associated with child active play ($\beta = 0.30$, $P < 0.001$). (2) Parental warmth was positively associated with child active play ($\beta = 0.15$, $P = 0.04$). Parental control and irritability were not significantly associated with child active play. (3) Parenting style was not associated with child active play. (4) After adjusted for parenting style, parental support remained positively associated with child active play ($\beta = 0.30$, $P < 0.001$). (5) Parenting style did not moderate the relationship between parental support and child active play behaviour.	6
Taylor et al. (2009) New Zealand [32]	Longitudinal	244	Baseline: 3 Follow-up at 4 and 5	(1) Mother's PA (2) Father's PA ((a) Actical accelerometers (b) Parent self-administered questionnaire)	Child PA ((1) Actical accelerometers. (2) Parent self-administered questionnaire)	(1) Child age (2) Child sex (3) Days of the week (week day/weekend day)	**Cross-sectional analysis:** (1) Parental activity was weakly associated with child's PA measured by AAC at 3 and 4 years but not 5 years (Spearman rank-order $r = 0.08$, $P = 0.034$ and $r = 0.17$, $P = 0.051$ for mothers and $r = 0.28$, $P = 0.001$ and $r = 0.23$, $P = 0.007$ for fathers for 3 and 4 years, respectively). (2) Mother's PA was associated with child's PA by parental ratings at 4 and 5 years but not 3 years ($r = 0.21$, $P = 0.003$ and $r = 0.18$, $P = 0.014$). (3) There was no association between parental ratings of their own and their child's PA. **Mixed model:** (4) Father's PA was a significant predictor of the child's PA measured by AAC (adjusted $\beta = 0.11$, $P = 0.024$). (5) Mother's PA was not significantly associated with child's PA measured by AAC (adjusted $\beta = 0.21$, $P = 0.062$).	6

MVPA: moderate to vigorous physical activity. PAEC-Q: Physical Activity and Exercise Questionnaire for Children. VPA: vigorous physical activity. NSA: nonsedentary activity. AOR: adjusted odds ratio. AAC: average accelerometry counts.

Table 3: Association between parental influence and children's screen time.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Barr-Anderson et al. (2011) USA [33]	Cross-sectional	431	Mean age 5.8 SD 0.51	(1) Parent TV time (2) Parent limit child's TV (3) Parental perception of child's screen time (parent self-administered questionnaire)	Child screen time (parent self-administered questionnaire)	(1) Intervention condition (2) Child age (3) Parent BMI (4) Relative socioeconomic status	(1) Parental TV viewing time was positively associated with child screen time ($\beta = 0.37$, $P < 0.001$). (2) Parent often or always limits child's TV was associated with less child screen time ($\beta = -0.38$, $P = 0.01$). (3) Parental perception that the child spent too much time playing video games was positively associated with child screen time ($\beta = 1.06$, $P < 0.001$).	6
Birken et al. (2011) Canada [34]	Cross-sectional	157	3	(1) Parent screen time (2) Screen time rules (3) Meals with the TV on (parent self-administered questionnaire)	Child screen time (parent self-administered questionnaire)	(1) Maternal education (2) Maternal age	(1) An increase of 1 hour of parental screen time was associated with 12 (95% CI 6–18) minutes of increase per day of child weekend screen time. (2) Screen time rules decreased child weekend screen time by 30 (95% CI 6–54) minutes per day. (3) Eating lunch in front of the screen was associated with 78 (95% CI 36–132) minutes of increase per day of child weekday screen time and 96 (95% CI 30–192) minutes of increase per day of child weekend-day screen time.	5

Table 3: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Bleakley et al. (2013) USA [35]	Cross-sectional	465	≤5	(1) Parent TV time (2) Coviewing TV with child (3) TV time restriction (parent self-reported online survey)	Child TV viewing time (parent self-reported online survey)	(1) Parental well-being (2) Media access TV in bedroom Number of TV sets PC in bedroom (3) Demographic Child gender Child age Parent race Parent education Parent income Parent employment Number of children	(1) Parent TV viewing was significantly associated with child TV time ($\beta = 0.47$, $P < 0.05$). (2) Coviewing TV with child was positively associated with more child TV time ($\beta = 0.16$, $P < 0.05$) (3) Parent TV time restriction was associated with lower child TV time.	5
Campbell et al. (2010) Australia [36]	Cross-sectional	140	1 ($n = 60$) 5 ($n = 80$)	(1) Maternal self-efficacy to promote PA to displace TV viewing (2) Maternal self-efficacy to limit TV viewing (parent self-administered questionnaire)	Children's TV (TV, DVD, and video) time (parent self-administered questionnaire)	No	(1) Maternal self-efficacy to promote PA to displace TV viewing was significantly inversely associated with both groups of children's TV time (Spearman rank order correlation −0.28 and −0.27, $P < 0.05$ for 1-year and 5-year-old children, respectively). (2) Maternal self-efficacy to limit TV viewing was significantly inversely associated with both groups of children's total TV time (Spearman rank order correlation −0.38, $P < 0.005$, and −0.31, $P < 0.05 = 1$ for 1-year- and 5-year-old children, respectively). (3) Mothers of 1-year-old children indicated significantly higher self-efficacy for limiting TV viewing than mothers of 5-year-old children ($P < 0.005$).	4

Table 3: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Carson and Janssen (2012) Canada [37]	Cross-sectional	746	≤5	(1) Parents' screen time (2) Parents' self-efficacy in reducing children's screen time (3) Parent attitudes regarding children's screen time (4) Parents' barriers to reduce children's screen time (5) Parents' perception of typical screen time in children (parent self-administered questionnaire)	Child screen time (parent self-administered questionnaire)	Sequential linear regression models adjusted for (1) Child age (2) Siblings (3) Education (4) Income (5) Family structure (6) Parental cognitions Multiple logistic regress models adjusted for (7) Child age (8) Child gender (9) Income (10) Parental cognitions (11) TV in bedroom (12) Video games in bedroom	**Sequential linear regression models** (1) Parents' screen time was positively associated with children's screen time ($\beta = 0.13$, 95% CI 0.07 to 0.19). (2) Parents' self-efficacy was negatively associated with children's screen time ($\beta = -0.38$, 95% CI −0.64 to −0.11). (3) Parents' attitude was positively associated with children's screen time ($\beta = 1.68$, 95% CI 1.19 to 2.17). (4) Parents' barrier was positively associated with children's screen time ($\beta = 0.99$, 95% CI 0.57 to 1.42). (5) Parents' perception of typical screen time in children was positively associated with children's screen time ($\beta = 1.16$, 95% CI 0.97 to 1.35). When separated children by 0–3 yr olds and 4-5 yr olds, parents' screen time and self-efficacy were associated with children's screen time for 4-5 yr olds, but not for 0–3 yr olds. **Multiple logistic regress models** (1) Parents' screen time was associated with children's high (top quartile) screen time (AOR 1.76, 95% CI 1.43–2.17). (2) Parents' self-efficacy was negatively associated with children's high (top quartile) screen time (AOR 0.62, 95% CI 0.49–0.78). (3) Parents' attitude was positively associated with children's high (top quartile) screen time (AOR 1.48, 95% CI 1.12 to 1.91). (4) Parents' barrier was not associated with children's high (top quartile) screen time. (5) Parents' perception of typical screen time in children was positively associated with children's high (top quartile) screen time (AOR 2.78, 95% CI 2.21 to 3.51).	6

Table 3: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Hinkley et al. (2013) Australia [38]	Clustered cross-sectional	935	Mean age 4.54 SD 0.70	(1) Maternal TV time (2) Paternal TV time (3) Parental concern about child screen time (4) Parent prefers child to do activities older children do (5) Parent believes the amount of TV child watches would not affect child health (6) Parental confidence to say no to child requests to play video games (7) Parent limits child TV view (parent self-administered questionnaire)	Child screen time (parent self-administered questionnaire)	(1) Child age (2) Child quiet play time (3) Maternal education (4) Physical environmental variables	**Boys** (1) Maternal TV time but not paternal TV time was negatively associated with boys meeting Australian/Canadian screen time recommendations (<1 hour/day) (AOR 0.90, 95% CI 0.84–0.97). (2) Boys were more likely to meet Australian/Canadian screen time recommendations if their parents had the confidence to say no to their child's requests to play video games (AOR 3.14, 95% CI 1.41–7.00). (3) Parent limits child TV viewing was not significantly associated with boys meeting Australian/Canadian screen time recommendations. **Girls** (1) Maternal TV time but not paternal TV time was negatively associated with girls meeting Australian/Canadian screen time recommendations (AOR 0.87, 95% CI 0.80–0.94). (2) Girls were less likely to meet Australian/Canadian screen time recommendations if their parents are concerned about their screen time (AOR 0.81, 95% CI 0.72–0.91). (3) Girls were less likely to meet Australian/Canadian screen time recommendations if their parent prefers child to do activities older children do (AOR 0.36, 95% CI 0.15–0.82). (4) Parent believes the amount of TV child watches would not affect child health was not significantly associated with girls meeting Australian/Canadian screen time recommendations. (5) Parent limits child TV viewing was not significantly associated with girls meeting Australian/Canadian screen time recommendations.	6

Table 3: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Kourlaba et al. (2009) Greece [39]	Clustered cross-sectional	2374	1–5	(1) Mother TV viewing time (2) Father TV viewing time (parent self-administered questionnaire)	Child TV viewing time (parent self-administered questionnaire)	Child: (1) Gender (2) PA Parent: (3) Educational status (4) Maternal employment (5) Time parents spent with children (6) Siblings	(1) In the total sample, parental TV time was significantly and positively associated with child TV time. (2) Mother TV time was significantly associated with TV time (≥ 2 h/day) of children aged 3–5 years (AOR 1.38, 95% CI 1.25–1.57) but marginally associated with children aged 1-2 years (AOR 1.24, 95% CI 0.94–1.79). (3) Father TV time was significantly associated with TV time (≥ 2 h/day) of children aged 3–5 years (AOR 1.24, 95% CI 1.15–1.42) but not children aged 1-2 years.	5
Rideout et al. (2006) USA [40]	Cross-sectional	1051	6 months–6 years	Parent TV time (parent self-reported telephone survey)	Children's TV time (parent self-reported telephone survey)	None	(1) Children whose parents watched TV ≥ 2 hrs/day watched averaging 17 minutes more TV per day than children whose parents spend 1-2 hrs/day (74 minutes versus 57 minutes, $P < 0.005$), and 28 minutes more TV per day than children whose parents spend <1 h/day (74 minutes versus 46 minutes, $P < 0.005$).	2

Table 3: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Schary et al. (2012) USA [41]	Cross-sectional	201	2–5	Parenting style (parent self-administered Child Rearing Questionnaire)	(1) Screen time (2) Quiet play time (parent self-administered questionnaire)	Child age Parent BMI	(1) Compared to neglectful parenting style, authoritative parenting style was associated with less child screen time on weekend ($\beta = -0.17$, $P = 0.05$ with adjusted model; $\beta = -0.26$, $P = 0.002$ with unadjusted model) and weekday ($\beta = -0.21$, $P = 0.01$ with unadjusted model). (2) Parenting style was not associated with child quiet play time.	6
Thompson et al. (2013) USA [42]	Longitudinal	217	Baseline: 3 months Follow-up at 6, 9, 12, and 18 months	Mother TV viewing time (parent self-administered questionnaire)	Infant TV exposure time (time spend in front of the TV) (parent self-administered questionnaire)	(1) Child gender (2) Visit	Mother TV viewing time was positively associated with infant TV exposure time (≥1 h/day) with AOR 1.27 (95% CI 1.12–1.44).	5
Vandewater et al. (2007) USA [43]	Cross-sectional	1045	6 months–6 years	(1) Parental TV time rules (2) Parental TV program rules (3) Parental perception TV helps (4) Parental perception TV hurts (5) Constant TV household (TV was on always or most of the time, even when no one was watching) (parent self-administered questionnaire)	Child screen time (parent self-administered questionnaire)	None	(1) Parental TV time rules were not associated with child TV time. (2) Parental TV program rules was associated with less likelihood of falling outside the AAP guidelines for 5-6-year olds (OR 0.33, 95% CI 0.12–0.90), but not for 0–2-year olds and 3-4-year olds. (3) Parental perception TV helps was associated with greater likelihood of falling outside the AAP guidelines for 0–2-year olds and 5-6-year olds, but not for 3-4-year olds. (4) Parental perception TV hurts was not associated with child TV time. (5) Constant TV household was associated with greater likelihood of falling outside the AAP guidelines for 3-4-year olds, but not for 0–2-year olds and 5-6-year olds.	3
Yalçin et al. (2002) Turkey [44]	Cross-sectional	187	3–6	(1) Mother TV viewing time (2) Father TV viewing time (parent self-administered questionnaire)	Child TV viewing time (hours/weekday) (parent self-administered questionnaire)	None	(1) The TV viewing time of children was significantly and positively correlated with that of mother and father (Pearson's $r = 0.49$, $P < 0.001$, $r = 0.53$, $P < 0.001$) (2) With multiple linear regression analysis the TV viewing time of mother and sibling were significant predictors of that of the child (adjusted $R^2 = 0.45$, $P < 0.001$, did not provide β).	3

AOR: adjusted odds ratio. AAP: American Academy of Pediatrics.

Table 4: Association between parental influence and children's PA time and screen time.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Gubbels et al. (2011) Netherlands [45]	Cross-sectional	2026	5	Parenting practices: (1) Restriction of sedentary behaviour (2) Monitoring activity (screen time and PA) (3) Stimulation to be active (parent self-administered questionnaire)	(1) Child PA time (minutes/day) (2) Child screen time (parent self-administered questionnaire)	Child: (1) BMI z-score at age 5 (2) Gender (3) Birth weight (4) Activity and eating style Parent: (5) BMI (6) Educational level (7) Employment (8) Country of birth (9) Maternal age	(1) Restriction of sedentary behaviour was related to more screen time ($\beta = 0.09$, $P < 0.01$) and less PA ($\beta = -0.19$, $P < 0.001$). (2) Parent monitoring activity was not associated with child PA time and screen time. (3) Stimulation to be active was positively associated with PA ($\beta = 0.12$, $P < 0.001$) and negatively with screen time ($\beta = -0.12$, $P < 0.001$).	6
Vandewater et al. (2005) USA [46]	Cross-sectional	838	6 months–6 years	(1) Parental TV time rules (2) Parental TV program rules (3) Parental negative attitude towards TV (4) Parental presence during children's TV use (parent self-administered questionnaire)	(1) Child TV time (minutes/day) (2) Child frequency of TV viewing (3) Child playing outdoor (parent self-administered questionnaire)	Child: (1) Age (2) Gender Family: (3) Household income (4) Family structure (5) Parent's education (6) Parent's minority status	(1) Parental TV time rule was negatively associated with child TV time ($\beta = -0.18$, $P < 0.001$). (2) Parental TV program rules did not predict less TV viewing by children (children whose parents have program rules watched 32.5 more minutes/day TV, $P < 0.001$). The relationship between program rules and child TV viewing was mediated by parental presence during viewing. (3) Children of parents with program rules tended to spend more time playing outdoors (mean difference of minutes playing outdoors = 17.7, $P < 0.1$). (4) Parental negative attitude towards TV was directly associated with child TV time ($\beta = -0.09$, $P < 0.05$) and was mediated by parental TV time rules. (5) Presence during children's TV use was directly associated with child TV time ($\beta = 0.29$, $P < 0.001$). (6) Children of parents with time rules and program rules tended to watch TV more frequently (mean difference of frequency watching TV were 0.28, $P < 0.0001$, and 1.07, $P < 0.001$, respectively).	4

Table 4: Continued.

Author (year) country reference	Study design	Sample	Age (years)	Parental influence (measurement)	Child PA (measurement)	Adjusted confounders	Main findings	Quality score
Smith et al. (2010) Australia [47]	Cross-sectional	764	1.7–5.6	(1) Parent self-efficacy in influencing child's PA and screen time (parent self-administered questionnaire)	(1) Child PA time (2) Child screen time (parent self-administered questionnaire)	(1) Child age (2) Child gender (3) Region (urban versus rural) (4) Maternal education (5) Household income (6) Barriers	(1) Parent high self-efficacy was associated with low likelihood of not meeting PA guidelines (<3 hrs/day) with AOR 0.36 (95% CI 0.21–0.60). (2) Parent high self-efficacy was associated with low likelihood of exceeding screen time recommendation (≥2 hrs/day) with AOR 0.62 (95% CI 0.43–0.87).	6
Spurrier et al. (2008) Australia [48]	Cross-sectional	280	4-5	(1) Role modelling Mother's frequency of walking >30 mins/day Mother's frequency of organised sport Father's frequency of walking >30 mins/day (2) Rules about screen viewing Frequency that TV is on Rules about TV viewing Parents limit exposure to TV advertising (parent self-administered questionnaire)	(1) Children's outdoor playtime (2) Children's screen time (parent self-administered check list)	No	(1) Parental participation in PA (mother's frequency of walking >30 mins/day and frequency of organised sport) was associated with greater outdoor play in preschool children ($P = 0.04$–0.008). (2) Sedentary activity rules (frequency that TV is on, rules about TV viewing, and parents limit exposure to TV advertising) were associated with greater outdoor play in preschool children ($P < 0.001$). (3) Fewer rules about TV watching were associated with increased sedentary indoor behaviour	3

AOR: adjusted odds ratio.

Table 5: Papers reporting an association between parental influences and children's PA.

Parental influences	Association with children's physical activity		
	Positive	Negative	No association
Parenting practices			
(1) Parents encourage/support PA	20, 21, 23, 24, 26, 30, 32, 45		25, 27, 28
(2) Parental rules			
Restricting rough games inside	24		
TV viewing rules	47, 48	45	
(3) Parent preference (child do the same activities as older siblings)		24	
Parent role modelling (parents' PA)	19, 23, 24, 27, 29, 31, 32, 47		22, 28
Parent perception			
(1) Parent perception of importance of child PA	23		32
(2) Parent perceptions of children's physical competence	26, 28		
Parental self-efficacy in PA	46		
Parenting style			30
Dimensions of parenting style (warmth)	30		

or let their child know that PA is good for health); (2) setting rules (e.g., restricting indoor games and having TV viewing rules); (3) parents preference (e.g., preferring child to do the same activities with their older siblings). For children's screen time, parenting practices included (1) setting TV rules (e.g., time or program rules); (2) watching TV with their child; (3) monitoring screen time; (4) having meals without watching TV; and (5) stimulating children to be active.

3.2.2. Parents' Role Modelling (Parents' Own PA and TV/Screen Time). Eight studies [19, 21–24, 28, 29, 48] used parent self-administered questionnaires to assess parents' own PA time, frequency, and intensity with two studies using accelerometer [20, 30] and one study using both parent self-administered questionnaire and accelerometer [32]. Nine studies used a questionnaire to measure parental TV time [33–35, 37–40, 42, 44]. Of them, two studies measured screen time rather than TV time [34, 37].

3.2.3. Parental Perceptions. Perception of importance of children's PA [23, 28] and perception of children's physical competence [21, 22] were reported in 4 studies. In examining children's screen time, perception of "too much screen time" [33, 38], "TV helps children's learning" [37, 43], or "TV hurts children's learning" [43, 46] were reported in five studies.

3.2.4. Parenting Self-Efficacy. Parental self-efficacy for limiting screen time was assessed by a single item: the level of confidence that parent could say "No" to their child's request for screen time (TV/computer/video games) [36–38]. One study assessed parental self-efficacy for influencing their child's PA in eight challenging situations such that the parent cannot think of activities to suggest; the parent is not able to participate in the activity [47].

3.2.5. Parenting Style. Only one study investigated the association of general parenting style and children's PA [31]. Parenting style was classified by using Maccoby and Martin's [49] classifications of parenting style with two dimensions - responsiveness (parental warmth/hostility) and demandingness (parental control).

3.3. Classification and Measurement of Children's PA and Screen Time. Children's PA was measured by parent self-administered questionnaire in 10 studies [19, 23, 24, 26, 27, 31, 45–48], followed by accelerometer in 7 studies [20–22, 28–30, 32], or heart rate monitoring and direct observation in one study [25].

Screen time was assessed by totaling the time spent on TV, DVDs, electronic game, and computer (n = 16 studies), which was always measured by parent self-administered questionnaire.

3.4. Parental Influences and Young Children's PA. Table 5 summarized the associations between parental influences and children's PA. Through examining three aspects of parenting practices on children's PA, there was moderate to strong evidence of linkage between parental encouragement/support and children's PA. For example, of 11 studies examining the relationship between parents' encouragement/support and children's PA, eight studies [21, 23, 26–29, 31, 45] with a mean quality score of 5.6 found that children whose parents encouraged or supported them to do PA were more likely to have higher levels of PA, yet three studies (with a mean quality score of 4.7) did not find such association [20, 22, 25]. The associations of setting rules and parental preference with children's PA were weak due to a small number of studies and inconsistent findings. One study (a quality score of 7) examining both setting PA

Table 6: Papers reporting an association between parental influences and children's screen time.

Parent influences	Association with children's screen time: Positive	Negative	No association
Parenting practices			
(1) Setting TV rules		47	
TV time rules	45	33, 34, 35, 48	38, 43
TV program rules	48	43	
(2) Coviewing TV with child	35, 48		
(3) Monitoring child screen time			45
(4) Meals with TV on	34, 43		
(5) Stimulation to be active		45	
Parent role modelling (Parent screen time)	33, 34, 35, 37, 38, 39, 40, 42, 44		
Parent perception			
(1) Perception that children spend too much screen time	33, 38		
(2) Parent perception TV helps	37, 43		
(3) Parent perception TV hurts		48	43
Parental self-efficacy in reducing child screen time		36, 37, 38, 46	
Parenting style (authoritative)		41	

rules and parent preference found that parental rules were positively associated with boy's PA, but parent preference was negatively associated with boy's PA [29]. Among three studies examining the association between setting TV viewing rules and children's PA, two studies (a mean quality score of 3.5) found that children with TV viewing rules spent more time playing outdoors [46, 48], which was not supported by Gubbels et al.'s study [45].

There was also moderate to strong evidence of positive association between parental PA level and young children's level of activity. Eight studies with a mean quality score of 5.1 found that parents' own PA level was positively associated with young children's PA [19, 20, 23, 28–30, 32, 48] with only two studies revealing no such association [22, 24].

Weak evidence was found in examining associations of parental perception, parental self-efficacy, and parenting style with children's PA due to limited studies and mixed findings. For example, contradictive findings were reported on parental perception of the importance of PA and children's PA in two studies [23, 28]. But another two studies found that parent perception of children's physical competence was positively associated with children's PA (MVPA) [21, 22]. Only one study found that parents who have a high sense of self-efficacy are more likely to have their children meeting the PA guidelines [47]. General parenting style was not found to be associated with child PA. However, parental warmth, one of the parenting style dimensions, was positively associated with child PA [31].

3.5. Parental Influences and Young Children's Screen Time. Table 6 summarized the associations between parental influences and children's screen time. Weak and mixed evidence was found in examining association between parenting practices and screen time. Of 7 studies examining TV time rules, four studies (a mean quality score of 5) found that setting TV time rules resulted in less screen time [33–35, 46] and two studies (a mean quality score of 4.5) found no such association [38, 43] with another study suggesting a negative effect of TV time rules on screen time [45]. Mixed evidence was found from two studies in examining setting TV program rules and screen time [43, 46]. The study conducted in 2005 found children whose parents had TV program rules watched more TV [46], but the finding was not supported by another study in 2007 [43]. In addition, one study revealed that more family rules about TV viewing were associated with less screen time [48]. Coviewing TV with a child [35, 46] and having meals when TV is on [34, 43] were associated with increased screen time. In addition, one study [45] found that monitoring child screen time was not associated with screen time, but stimulating a child to be active was associated to less screen time.

In contrast to parenting practices, the review found that there was moderate evidence suggesting parental self-efficacy and parents' own TV time were associated with children's screen time. Nine studies with a mean quality score of 4.8 consistently revealed that parents' own TV time was positively associated with their child's screen time [33–35, 37–40, 42, 44]. The evidence was also consistent in four studies (a mean quality score of 5.5), which concluded that high parental self-efficacy in reducing children's screen time was associated with less screen time in children [36–38, 47].

In terms of associations of parental perceptions and parenting style with screen time, the evidence was weak and inconsistent from only four studies reviewed. For example, two studies revealed that parental perception of their child spending too much time on playing video games or watching TV was associated with increased screen time [33, 38]. Parental perception of "TV helps" was found to be associated with increased screen time [37, 43]. Parental perception of "TV hurts" was associated with decreased screen time [46]. But this association was not supported by another study conducted by the same author [43].

The authoritative parenting style was found to be associated with decreased children's screen time by only one study [41].

4. Discussion

By critically assessing and synthesizing evidence from individual studies, the present systematic review updates the current literature and fills knowledge gaps in relation to associations of parental influences with young children's PA and screen viewing behaviours. Moderate to strong evidence was found in relation to the associations of parental encouragement/support for PA and parents' own PA level with children's PA. Moderate evidence was also found regarding associations of parental self-efficacy and parents' own screen time with children's screen time. Associations of other aspects of parenting practices, parental perceptions, and parenting style with children's PA and screen time were indeterminate due to limited studies and contradictory results from studies included in this review.

4.1. What Is Already Known? Three previous systematic reviews summarised mixed evidence of associations of parents' PA and parental encouragement/support with children's PA [10, 12, 16]. Hinkley et al. and Mitchell et al. concluded that parents' PA was positively associated with young children's PA [12, 16], while de Craemer et al. found indeterminate association [10]. Likewise, Mitchell et al. found that there was positive association between parental encouragement/support and children's PA [16], yet Hinkley et al. and de Craemer et al. found no such association [10, 12]. Another systematic review that included several qualitative studies suggested that parent involvement, encouragement, and modelling of PA may be important influences impacting young children's PA and are worthy of further systematic study [50].

Of four previous systematic reviews of association between parents' TV time and children's screen time, two concluded a positive association [9, 11], while the other two found that there was a positive but indeterminate association [10, 13]. Mixed findings about the association between parental TV rules and children's screen time were reported by three reviews [9, 10, 13]. Cillero and Jago and Hinkley et al. found that children with TV rules had less screen time [9, 13], while de Craemer et al. found that this association was indeterminate [10].

Mixed evidence in relation to associations of parental influences with children's PA and screen time was further explored by some qualitative studies. For example, Dwyer et al. found that that parental modelling and/or encouragement of activity was a key influence and predictor of PA and sedentary behaviour in children, which was especially acknowledged by parents [51]. Another qualitative study found parents' own screen viewing habits was one of the two most frequently mentioned factors that influence children's screen time (the other one was weather conditions) [52]. Parents also liked the idea of implementing parental rules for TV viewing (e.g., time rules, no TV viewing during meals) [52].

4.2. What This Study Adds. The present review examines the evidence of associations of parental influences with both PA and screen time of young children. Findings from the review generally support and reinforce the evidence found in some of the previous reviews. This review also examined the role of parental rules for PA and screen viewing, parent perceptions of children's PA, and screen viewing and found their effects on children's PA and screen time remained indeterminate because of contradictive findings or a small number of studies.

Unlike previous reviews that only focused on parenting practices, the present review also explores parental self-efficacy and general parenting style as part of the parental influences. Moderate evidence was found that increased parental self-efficacy was associated with reduced children's screen time. But, the effect of parental self-efficacy on increasing children's PA cannot be concluded with only one study found in this review. The association of parenting style with children's PA and screen time remains unclear due to the limited number of studies.

4.3. Evidence Gaps and Future Research. Despite substantial evidence suggesting that an authoritative parenting style was associated with older children's PA and sedentary behaviours [53, 54], the present systematic review was not able to make such conclusion for young children with only one study included in the review [31, 41]. Therefore, the associations of parenting style and young children's PA and sedentary behaviours need more attention in future research. In this review, only one longitudinal study found that the relationship between parent's PA and preschool children's PA was stronger than that in older children (at follow-up) [32]. It seems likely that the associations of various parental influences and children's PA and screen viewing behaviours would change with advancing age of children. Hence, further longitudinal research on parental influences is needed. In addition, there is a clear evidence gap regarding the effect of parental self-efficacy on children's PA.

As discussed above, associations of some parenting practices (e.g., setting PA and TV rules) and parental perceptions with children's PA and screen time are still indeterminate and further investigation is needed to inform the development of health promotion programs. Inconsistent findings of the association between setting TV rules and children's screen time could be a result of different levels of obedience of rules. One qualitative study involving six European countries revealed that, in general, parents of preschool-school children only had informal rules about TV viewing [52]. In this review, two individual studies were conducted by Vandewater et al. in United States in 2005 and 2007 [43, 46]. The first study found that parental perceptions of "TV hurts" and setting TV time rules were associated with decreased screen time [46]. However, such associations were not found in a later study [43]. It may be that the association between parental perception of "TV hurts" and children's screen time was related to setting TV time rules. Thus, more research is needed to investigate whether the parental perception of TV "hurts" influences establishing and enforcing TV rules. In addition, whether parenting practices are moderated by general parenting style also needs to be investigated.

5. Conclusions

In the early years of life, some parental influences were significantly associated with young children's PA and screen time with moderate to strong evidence. Results from the present review suggest that parents' encouragement and support can increase their children's PA and reducing parents own screen time can lead to decreased child screen time. Improving parenting practices, parental self-efficacy and parenting style may also be promising approaches to increasing PA time and decreasing screen time of young children.

Strengths and Limitations of This Review

One of the strengths of this review is that we used comprehensive and systematic inclusion and exclusion criteria and a modified quality assessment tool for the critical appraisals of papers. With this quality assessment tool, the strength of evidence from individual study could be assessed based on a quality assessment score. In the present review, the concept of parental influences included not only parents' role modelling and parenting practices that were commonly included in previous reviews, but also general parenting style, parental self-efficacy, and parental perception of PA and screen time, which are important aspects of parenting. In addition, this review searched six databases which enable a wider range of studies to be found.

However, due to the heterogeneity of studies included in the review we were not able to conduct a meta-analysis. Evidence derived from this review was limited by various measurements used regarding parents' and children's PA as well as aspects of parental influences. The definition of children's screen time was inconsistent in the papers reviewed. Study sample sizes in these papers reviewed noticeably varied from 69 to 10,694 where small sample size undermines the study findings. In addition, most studies were cross-sectional which means it is difficult to make causal inference. Therefore, consideration must be given when interpreting the results.

Conflict of Interests

The authors declared no conflict of interests with respect to the research, authorship, and/or publication of this paper.

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Research Article

Latino Family Childcare Providers' Beliefs, Attitudes, and Practices Related to Promotion of Healthy Behaviors among Preschool Children: A Qualitative Study

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Background. The continuing rise of obesity among Latinos is a public health concern with an immediate need for early prevention. Changes in family structures have increased demand and reliance for child care for young children. Latino children are the fastest-growing segment of the child population in the United States, and research shows that Latino families use preschools and day care centers much less than those of other ethnic groups, apparently because of cultural preferences for family-like care. *Objectives*. Given that many low income Latino children attend family child care homes (FCCHs), there is a need to explore the role that FCCH providers may play in establishing and reinforcing children's early healthful eating and physical activity behaviors and consequently in the prevention of childhood obesity. *Design*. Using purposive sampling, six focus groups were conducted in Spanish with licensed Latino FCCH providers ($n = 44$). Data was analyzed to identify recurrent themes. *Results*. Latino FCCH providers described how they play an influential role in promoting healthful eating and physical activity behaviors of preschool children in their care. They also identified many barriers and challenges in establishing and maintaining healthful nutrition and physical activity behaviors, including high cost of healthy foods, cold weather, and physical environment of FCCH. *Conclusions*. Latino FCCH providers can have a strong impact in promoting healthful behaviors in low-income, Latino communities. They may be able to effectively deliver interventions targeting low-income, minority families to promote healthful eating and physical activity behaviors and prevent child obesity.

1. Introduction

Latinos are the largest and most rapidly growing population group in the United States. Although rates of childhood obesity are still high for the general child population, children of low-income, minority families are at a particularly high risk of overweight and obesity [1]. The continuing rise of obesity within minority and immigrant populations, particularly Latinos, remains a pressing public health concern with an immediate need for early prevention.

Children living in the United States live in a society that has changed dramatically since the obesity epidemic first developed. Changes in family structure, gender roles, and families' needs for economic security have increased the demand and reliance on child care for children at increasingly younger ages. In addition, welfare reform laws requiring employment have increased the number of employed low-income parents and have contributed to an increase in the number of children enrolled in child care programs [2]. In 2012, 68% of women with children under the age of 6 were either working or looking for work, and almost 11 million preschool-aged children received some form of child care while their mothers worked [2, 3].

The child care setting is an important social environment that potentially influences the development of children's early dietary and physical activity habits and consequently contributes to the development of child overweight [4–6]. Given parents increasing reliance on child care settings for their children at continually younger ages, these settings are likely important venues for the implementation of programs and policies to help children develop healthful eating and physical activity habits [2, 4].

Child care providers, like parents, help establish and reinforce early healthful eating and physical activity habits among young children and can be key players in preventing childhood obesity by developing a child care environment that fosters healthful eating and physical activity behaviors among children [7–9]. Child care provider's knowledge of nutrition and physical activity, the selection of food and meals, structure within their daycare, and their own modeling of behaviors are all influential in young children's development of lifelong habits that contribute to normal weight or to overweight and obesity [10–12]. In fact, research suggests that child care providers may be more influential than or equally as important as parents in shaping food preferences of young children [13, 14]. Child care settings may help establish and reinforce children's eating and physical activity habits [4, 14, 15]. Furthermore, studies have found that Latino parents who send their children to child care believe these settings are instrumental in shaping and reinforcing the eating and physical activity of their children [14]. However, despite the growing number of studies and interventions targeting child care settings and given that more than 1.6 million children attend FCCHs [16], there is limited research examining FCCHs and their influence on the development of healthful eating and physical activity habits in Latino preschool-aged children, a group at increased risk of obesity [17].

In Massachusetts, the setting for this study, the majority of children enrolled in FCCHs are from minority backgrounds, including a high percentage of Latino children [18], and most Latino children attend FCCHs operated by Latino staff [18]. FCCHs are licensed by the Massachusetts Department of Early Education and Care (MA-EEC). FCCH providers are required to (1) have a plan for communicating with parents/guardians through various communication channels (e.g., handbooks, newsletters, and notes); (2) provide opportunities for outdoor and indoor active play; (3) have adequate indoor and outdoor space and equipment for active and safe play; and (4) provide opportunities for children to develop gross and fine motor skills [19]. State regulations do not specify the amount, frequency, and type of physical activity or regulate television use [19]. Additionally, FCCH providers may be eligible to participate in the Child and Adult Care Food Program (CACFP), which requires that CACFP participants follow USDA/CACFP guidelines for menus and feeding practices [20]. Given the growing importance of FCCHs in serving a large proportion of minority, low-income children, further research is needed to examine the role that FCCH providers play in establishing and reinforcing children's early healthful eating and physical activity habits and consequently preventing childhood obesity. Moreover, given the high rates of obesity among Latino preschoolers [17], and the fact that Latino families use preschools and day care centers much less than those of other ethnic groups, apparently because of cultural preferences for family-like care, there is a need to understand how family child care settings influence the development of eating, physical activity and sedentary behaviors associated with childhood obesity.

"Preventing Obesity in Latino Family Child Care Homes" is a multicomponent study employing qualitative methods to explore influences on eating habits, physical activity, sedentary behaviors, and ultimately risk of obesity among Latino preschool-aged children attending FCCHs in Massachusetts. Additionally, the study assessed practices, policies, and regulations of FCCHs that may be associated with risk of childhood obesity among Latino preschool-aged children. This current paper focuses on the results of the qualitative research examining Latino FCCH providers' beliefs and practices related to nutrition and feeding, and physical activity and sedentary behaviors among low-income preschool children.

2. Methods

2.1. Sample Selection and Recruitment. We worked with MA Department of Early Education and Care (EEC), which develops licensing regulations and requirements for childcare providers and supports training for early educators, and the Child Care Circuit, a nonprofit organization providing child care referrals, training, and parent and provider services, to identify cities in four regions of the state (North Shore, Greater Boston, Central MA, and Western MA) that have a large number of FCCHs run by Latino providers. MA-ECC and the Child Care Circuit, then identified two agencies that work directly with FCCH providers, CACFP, and Family Child Care Systems who compiled a list of all currently licensed Latino FCCH providers. From this list, we randomly selected 22 names per region of the state, with a goal of recruiting 8–12 individuals to participate in one focus group session in each region. We mailed all selected providers a recruitment flyer in Spanish that included a phone number that interested providers could call to obtain more information and/or express interest in participation. Interested providers who called spoke with a native Spanish speaker who explained the study and its purpose. A confirmatory/reminder phone call was made one to two days before the scheduled focus group session.

2.2. Focus Group Procedures. Focus group discussions were held in meeting rooms of public libraries, and all participants provided written informed consent. A native Spanish speaker trained in qualitative research methods conducted all focus groups in Spanish using a semistructured discussion guide including open-ended questions and probes. Focus group discussions were audio-taped with oral consent of participants. At completion of the focus group, participants received a $25 cash incentive and completed a brief demographic survey. The study protocol was approved by the Internal Review Board at the Harvard School of Public Health.

The focus group guide explored (1) providers' perceptions, attitudes and practices related to nutrition, and physical activity and sedentary behaviors; (2) influences of FCCH characteristics on children's eating and physical activity behaviors; (3) FCCH providers practices related to nutrition and physical activity; (4) educational activities offered by state and local agencies related to nutrition and physical activity and sedentary behaviors; (5) communication between FCCH providers and parents about FCCH practices and policies related to nutrition and physical activity and sedentary behaviors; and (6) barriers FCCH providers face in providing an environment conducive to healthful eating and physical activity behaviors. See the following for sample of questions used in focus group discussions with Latino family child care providers (FCCPs).

FCCHs' Beliefs, Attitudes, and Practices Related to Child Feeding Practice

(i) Please describe your routine, or plan, for meals that you give the children. (e.g., describe how you use menus, what times you serve meals?)

Please tell me about your plan or routine for giving snacks to the children.

For example, frequency that you give snacks to children, and so forth.

(ii) What do you use to help you plan meals and snacks?

For example, books, websites, agencies, other providers, and so forth.

(iii) What things affect your choice of foods that you typically serve? Please give a few of the most important reasons for your food choices.

For example, cost, rules, or guidelines from food program, cultural values and tradition, good for health, family member's advice, easy to prepare, and so forth.

(iv) How much food you think a child should typically eat at a meal? (e.g., *what is too much, not enough)*

(v) What are you and the children doing during meals? (e.g., sitting together at a table, watching TV or videos during meal)

FCCPs' Beliefs, Attitudes, and Practices Related to Physical Activity

(i) What are your ideas and thoughts about physical activity for children (in general)?

(ii) Tell me about the routine you have for children to get physical activity while they are at the daycare.

For example, how much time for PA daily, time of day, and so forth?

(iii) Why do you have this routine?

(iv) What kinds of ways are children active outdoors on a typical day?

For example, do they play games and use equipment?

(v) What kinds of ways are children active indoors on a typical day?

For example, do they play games, use equipment, and use videos or TV?

(vi) If you wanted to get more information about how much PA children need or get ideas about how to help kids be active, how would you do this?

FCCPs' Beliefs, Attitudes, and Practices Related to Sedentary Behaviors. We know that all children like to watch cartoons and other shows like Dora the Explorer. They also enjoy playing on a computer, cell phone, DS toys, and video and Nintendo games. We call these "screen time."

(i) What are your thoughts in general on screen time for children aged 2 to 5?

(ii) What rules or routines do you have about screen time?

(iii) What do parents think about these rules?

Providers' Beliefs, Attitudes, and Practices Related to Communication with Parents

(i) How do you typically let parents know what their child did while at care, especially what they had to eat and what they did for physical activity?

(ii) What, if anything, do you discuss with parents about their child's weight?

(iii) Who would you talk to for advice if you thought a child was too thin or weighed too much? (family member, doctor, WIC staff, other)

2.3. Analysis. Audiotaped discussions were transcribed in Spanish and then translated into English by a bilingual consultant. The analysis plan, which used a content analysis approach, included an initial review of all translated transcripts by two members of the study team who also developed a codebook. Two coders trained in qualitative methods independently read and analyzed transcripts to identify salient convergent themes [21]. All transcripts were then coded based on broad categories of the areas of inquiry of the focus group guide. Inconsistencies in coding were discussed and resolved. Within these areas, emerging subthemes were identified and each one was assigned a specific code. Descriptive analyses and frequencies were calculated from sociodemographic questionnaires using Microsoft Excel 2008.

3. Results

In total, 44 providers (41 females, 3 males), all of whom are self-identified as Hispanic/Latino, participated in six focus groups. About one-third of participants ($n = 14$) had graduated from high school or earned their GED, and close to forty percent ($n = 17$) had attended some college. Most ($n = 41$, 93%) had several to up to 25 years of experience running FCCHs. Data analysis identified key themes related to nutrition and feeding practices, physical activity, and sedentary behaviors at Latino FCCHs. Emergent themes are discussed below, with quotes used to illustrate central points.

3.1. Nutrition and Food Practices

3.1.1. Foods Served and Portion Sizes. Providers reported that foods served for breakfast often include 1% milk, fruit, yogurt, cereal, oatmeal, pancakes, and freshly squeezed or 100% juice. Lunch typically includes rice and/or beans, meat, and vegetables. Providers also mentioned that they do not allow or serve certain foods. Prohibited foods included juices that are not 100% juice, soda, hot dogs, and fried foods.

Providers indicated that they use guides from food programs (e.g., USDA) to determine portion sizes. Some mentioned using measuring cups to determine portion sizes while others spoke of using informal tools such as small plates. Many providers mentioned basing portion sizes on children's ages, which they believed to be an important factor in determining the quantity of food a child should eat.

Providers believed that children eat a healthier diet in their FCCHs than they do at home and that parents are supportive of FCCH policies. *"The parents that I have always feel good about what I give the kids because sometimes they do not have the time to prepare food like we prepare it with all of the nutrients, like vegetables, everything a child needs in a day."* Most providers perceived parents as being too tired and busy to make healthy meals at home and that parents were more permissive then they were of their children eating unhealthy foods. "*Sometimes, if parents are alone, they do not make healthy meals because they do not have the motivation. They get home and ate too tired. . .*"

3.1.2. Providers' Beliefs and Practices Related to Child Feeding. Most providers felt their role was to nurture and educate children in their care and viewed providing "good nutrition" and "healthy diets" as a priority. Several providers spoke of the need to compensate for unhealthy practices at home by parents. They also felt that it is important to expose children in their care to healthy foods and eating habits. Most providers reported being confident about their abilities to serve healthful foods at their FCCH and viewed themselves as "educators," with the knowledge needed to teach children and their families about healthful diets. *"I try to inform the parents if there are activities in the community geared towards healthy eating and living for families . . . I give them pamphlets and all sorts of things that I have access to because of my work as a FCCH provider and that they may not be aware of."*

In addition, most providers viewed themselves as "educators" and "professionals" and were vocal about wanting to discourage the perception of FCCHs providers as being just "*babysitters.*" Providers also spoke of enjoying seeing the children that they once cared for progressing, growing up, and being successful. *"It makes us feel good that we did the job we needed and those children will not have a hard time when they start school."*

3.1.3. Strategies to Incorporate Nutritious Foods. Providers across all focus groups spoke of multiple strategies they use to incorporate nutritious foods into meals and snacks. Strategies included becoming familiar with foods served and meal time practices at the homes of children attending their FCCH, introducing and encouraging new and healthy foods, and modeling of healthful behaviors. Some providers spoke of encouraging new foods by directly involving children with healthy food choices, as they believe this gives children a sense of control and increased openness to new foods, especially if they see their peers enjoying foods they would not normally eat. *"I usually allow children to help pick their foods as part of a game at the beginning of the week, so that they have some choice of preferred foods."* In addition, some providers mentioned that children themselves influence food choices and eating habits of other children. *"At first a child may not want to eat something, but when they see another child eating it, they will try."*

3.1.4. Meal Planning. The majority of providers mentioned the importance of planning, buying, and preparing meals in advance. They felt planning ahead enabled them to serve a healthy and varied food menu on a weekly basis. Planning was seen as especially important for providers who served multiple meals (e.g., breakfast, a morning snack, lunch, an afternoon snack, and, in some cases, dinner). *"I like to plan ahead and know what I will serve the kids for at least a week . . . it's just much easier that way."*

Across all focus groups, nearly all providers mentioned using available educational resources, including *Minute Menu* for their food shopping and planning needs of the week. *Minute Menu* is a computer software program affiliated with CACFP. A few providers mentioned that *Minute Menu* made it easy to "print a shopping list" for their meals and allowed for some flexibility in their preplanned menus. *"If a child does not like one vegetable they can substitute another vegetable in its place."* Other resources included online "school-based menus" and menus provided by their local food programs such as "*Yours for Children.*" A few providers also reported that they use pamphlets from the USDA for snack and food ideas. *"They are always sending magazines on how to use the things to feed the children better and won't lead them into becoming obese children."*

3.1.5. Educational Workshops. The majority of providers mentioned participating in workshops about nutritional guidelines and using workshop resources to guide healthy eating options at their FCCHs. A few stated that attending these workshops and trainings caused them to make changes to their feeding practices and meal options at their FCCHs. *"I went to a workshop where they showed you how much sugar is in juice as measured by the number of sugar packets. After that workshop, I have just paid a lot more attention to serving juices to the children."*

3.2. Factors That Influence Foods Served by FCCH Providers

3.2.1. Cost of Healthy Foods. Several barriers to providing healthy foods in FCCHs were mentioned, including the high cost of healthy foods, especially organic and fresh fruits and vegetables. *"Something that affects is money, how much they [food program] pay you. Everything is so expensive, especially organic food. You have to pick out what is cheaper that week, fruit or vegetables, to be able to save money."*

3.2.2. Latino Culture. Most providers acknowledged that their Latino culture influences the foods they serve at their FCCH as well as eating routines and the foods that children eat with their families outside of the FCCHs. *"Cultures can positively or negatively affect people's food choices. A child comes to my home as an infant and grows with me. It does not matter what nationality they are. They learn to eat in my daycare and learn to eat food from my culture."*

Although providers felt their Latino culture influences the foods they serve, they did not see their culture as negatively impacting foods they provided at their FCCHs. On the contrary, several providers noted several healthy food options that are part of the Latino culture, such as beans. *"I think that the Latino culture includes many food options. For example, I serve bean soup to the kids on a regular basis and that's very healthy for them."*

3.2.3. Perceptions of Child Weight Status. A few providers reported having some children "at risk" of overweight or obesity in their care and that this influenced their feeding practices, especially in determining portion sizes. *"I try to reduce the portion of the one that likes to eat so he won't get to eat too much and later be affected by obesity."* While another added, *"I may have the child wait to see if they are still hungry then "give water or fruit" if the child is still hungry."* Furthermore, some FCCPs felt that they needed to "control" what and how much children eat. *"We cannot let them eat everything they want."*

3.2.4. Perceptions of EEC and CACFP Policies. The majority of providers was aware and supportive of EEC and CACFP policies, regulations, and guidelines for both nutrition and physical activity behaviors of children attending FCCHs. They felt these policies made a real difference in the health of children attending FCCH. *"I think the EEC regulations require that children engage in an hour or more a day of PA, but a minimum of an hour a day. I agree with that."*

3.3. Physical Activity and Sedentary Behaviors

3.3.1. Beliefs about Physical Activity and Sedentary Behaviors. Across all focus groups, the majority of providers described physical activity as engaging in organized activities, such as throwing a ball, swinging, dancing, and climbing, or as general activity throughout their day, such as running around during free-play. The general consensus was that physical activity is an important part of children's daily routine at FCCHs. Although most providers reported children being very active throughout the day and agreed on the importance of physical activity as part of children's daily routine at their FCCHs, the amount of time providers believed children should engage in physical activity ranged from 30 minutes to two hours.

3.3.2. Practices Related to Physical Activity. When asked to discuss how they ensure that children attending their FCCHs are physically active, the majority of providers described creative methods such as use of small outdoor and indoor equipment including hula hoops, jump rope, small trampolines for keeping children active throughout the year including during the cold winter months. Several providers described creative methods for keeping children active during cold winter months including having children use indoor equipment such as hula hoops, jump rope, and small trampolines. *"When we are inside, we use dancing a lot." "I use the second floor staircase."* Some providers spoke of making modifications to their homes, both indoors and outdoors to make it more conducive to physical activity. *"In my house we redid the basement, so the kids have a big space to play, jump, and use hula hoops."*

Most providers felt that screen time should be regulated and that children should be allowed a maximum of one hour of screen time per day. TV viewing was the most common type of screen time. Many providers reported allowing children to have screen time during transition times such as dropoff, pickup, and meal preparation. *"I let them play computer games for about 15 minutes. And some TV when I am preparing the food, but no more than an hour a day."* A few providers seemed to make a distinction between screen time for educational purposes and screen time for entertainment and felt that as long as the TV was being used for educational purposes it was "Ok" to let children watch 30–60 minutes of TV a day. *"I think it's Ok for the kids to watch some educational program on TV such as the PBS programs. Some of those programs are very good and teach the kids basic language skills."* Although most providers reported that the majority of parents do not mind their kids watch some TV while at the FCCH, a few mentioned that they respect and find alternative for children whose parents do not want them to watch any TV while at FCCH. *"I have a parent who really does not want her daughter to watch TV while at daycare. I respect that, so when the other kids are watching TV, I have her draw."* Although the majority of providers did not express concerns or challenges with limiting screen time, a few providers noted that some parents allowed their children to bring electronics to daycare even when there were rules against that. *"I have a hard time when parents don't respect the rules that I have around children bringing and using electronics such as DS. I don't really like to have to keep reminding them that those devices are not allowed in my FCCH."* Nevertheless, a few providers noted that some parents allowed their children to bring electronics to daycare, even when there are rules against that, which was viewed as challenging.

3.3.3. Barriers to Physical Activity. Across all focus groups, nearly all providers noted obstacles to children being physically active with lack of space and the cold weather being the most frequently noted. *"It's really hard to keep the kids active when it's cold and they don't have as much space to* *move around inside the house."* In order to overcome these barriers some providers mentioned creative ways to ensure that children engage in PA while at their FCCHs. *"My home is not that big, so we often play a game and use the stairs. I have the kids go up and down a few times..." "My house is small, but I have a house with two garages and inside there is a ball, and things saved for winter, and we begin to throw a ball and move around in there and we maintain our activity level."* Furthermore, some providers reported taking children to nearby parks or going for short walks around their homes, when the weather allowed. *"Whenever the weather is good I take the kids to a park near the house."*

Many providers felt children were less active during the winter in comparison to the summer due to the cold weather when children spent more time indoors. A few providers noted that it can take a long time to get all children's winter gear on and off, and that can be especially challenging if they take care of several children. "*I only take them out once a day [in winter] because it is hard to put all the coats, gloves, hats."* Furthermore, providers who had grown up outside the US, in warmer climates appeared to perceive the cold weather as a barrier more than providers who had grown up with cold weather. *"I was born in the Dominican Republic. I am not used to the kind of cold weather we get here in MA. I do not think I will ever get used to it . . . I just try to get through the winter. It can be difficult."*

3.4. Communication with Parents

3.4.1. Attitudes and Practices Related to Communication with Parents. Nearly all providers spoke of the importance of having effective, open, and ongoing communication with parents as most children spend most of the day in their care. Most providers reported sharing information regularly with parents about children routines, what and how much they ate, and anything unusual such as an illness or injury. Furthermore, many providers felt that ongoing communication with parents is critical, as it allows them to understand children's home environment including family's routines and practices, how these shape the socio-emotional and physical development of the children they care for. *"Communication with parents is also very important because it gives us a chance to learn about the child's home environment, the family's routines and rules, which is really important information to have to understand and care for the child in our FCCHs."*

3.4.2. Communication Methods. Providers used multiple communication channels, including notes sent home at the end of day, forms, in-person communication, emails, texts, phone calls, and bulletin boards, where parents can see when they pick up/drop off their children. In fact, bulletin boards were used at most FCCHS. *"I tell them what the children have done, we talk about the progress of the child, what vocabulary they have learned, things like this, if the child has a necessity, how we can help the child, the resources in the community to help..."*

3.4.3. Food-Related Communications. Several providers report sharing menu information with parents. *"I like to give the weekly menu to parents at the beginning of the week so that they understand and know what I am feeding their child at my FCCH and that I will serve a variety of foods."* Other providers reported giving hard copies of a weekly/monthly meal menu to parents, while others reported posting it on an online bulletin board. A few providers reported using a software program provided by their local food program to report children's daily food consumption and physical activity. Providers who used such software stated they really liked using the software for its easiness of communication with parents. *"I like it because all the information can be easily emailed to parents."*

3.4.4. Communication Related to Weight Concerns. When asked how comfortable and confident they feel about talking with parents about any concerns they might have about a child' weight status, most providers reported feeling very comfortable and confident. However, the majority of providers reported that they did not have major concerns about weight status of children currently under their care. A couple of providers who reported having an overweight child under their care in the past mentioned that they felt comfortable and confident approaching the child's mother, discussing their concerns and sharing resources with the mother. *"A year or so ago, I had a child in my home (FCCH) who was overweight. So, I approached the mother and talked to her about my concern. I told her that I believed she should check with her pediatrician. I also told her about a training that I had attended and how during this training the instructor had stressed the importance of keeping children active, not allowing them to drink lots of sugar sweetened drinks, and having them eat plenty of fruits and vegetables . . ."*

A few providers stated that they did not feel comfortable discussing children's weight status with parents. *"It's kind of difficult because when I think of children I've encountered who were overweight, usually the parents are overweight."* Providers who reported being reluctant to discuss child's weight felt that parents can be very sensitive to other people's perceptions of their children, and because of that they preferred not to talk about it with parents. Additionally, some providers felt that it is hard to change families' habits and that parents are not always open to advice. *"It is very difficult to educate the parent sometimes. Parents feed her a lot of McDonalds so I have tried to give them information on my menus so they can take [sic] home."* There were, however, a few providers who felt it was their responsibility and part of their "job" to approach parents if they had concerns about a child's weight status. *"I feel it is part of my job to let parents know any concerns I have about their child, and that also goes for any concerns related to a child's weight status. I agree that it is not always easy to talk about it, and that parents can be sensitive sometimes, but I still think it is my responsibility."*

4. Discussion

In this study, theory-driven qualitative research methods were used to assess Latino providers' beliefs and practices related to promoting healthful dietary and physical activity behaviors among preschool children attending FCCH. Theory-driven qualitative approaches are critical to enhancing knowledge and guiding development of interventions that promote healthful behaviors related to pediatric obesity intervention [22, 23].

Study findings indicate that Latino FCCH providers are vested in and believe they are influential in promoting healthy eating and physical activity behaviors of the preschool children in their care. In agreement with previous studies focusing on child care centers and family child care homes, Latino FCCH providers participating in our study perceived their role beyond simply "watching children" to one that includes promotion of early healthy behaviors including nutrition and physical activity [13, 24, 25].

Analysis revealed a few barriers and challenges faced by providers in establishing and maintaining healthful nutrition and physical activity practices in their FCCHs, including financial constraints. Several providers referred to high costs of fruit and vegetables, especially organic types, as a potential limiting factor. This finding is consistent with studies showing that low socioeconomic and neighborhood settings are an important factor influencing residents' consumption of healthy food choices, such as fruits and vegetables [14, 26].

Latino FCCH providers participating in our study reported using strategies such as, encouragement and role modeling to influence healthy food choice and consumption, particularly with regard to introducing new foods and increasing variety. Our findings are in agreement with that of a previous study by Hughes et al. [27] conducted with Latino Head Start providers highlighting the important influence that child care providers have in the development of healthy and unhealthy eating behaviors in minority children [27–29]. Contrary to a recent longitudinal survey study by Lanigan [30], Latino providers in our study did not report negative practices including pressuring child to eat and rewards for eating foods, although our qualitative study has a small sample size ($n = 44$).

Although most providers were consistent regarding mealtime food choices and routines, we found varied interpretations of portion size. This suggests that providers may benefit from additional training that assesses and addresses provider's knowledge and educates providers about evidence-based practices related to healthful eating and child feeding practices [31–33].

In general, Latino providers in our study perceived parents as not being aware of the importance of healthful eating practices and/or lacking the time needed to ensure that their children ate a healthful diet. In addition, most providers felt that it was part of their "job" to engage with and educate parents about the importance of proper child nutrition and healthy eating behaviors. This finding is consistent with findings from recent studies [13, 24, 34] which indicate the important role that child care providers can play in the promotion of children's early healthy behaviors related to eating and physical activity [13].

Our findings regarding providers' positive beliefs related to child nutrition and feeding practices suggest that regulations and resources, particularly those promulgated by CACFP, are important factors influencing Latino FCCH providers' knowledge and practices related to nutrition and child feeding. Providers spoke positively about educational opportunities available to them through training and workshops required for licensing of their FCCHs. This finding is in agreement with that of Stan et al. [31] documenting that broad-scale, in-person training is well received by child care providers and can be effective in increasing child care providers' knowledge of regulations to promote healthful eating and child feeding practices in child care settings, including FCCHs [32].

Our results revealed that in general, FCCH providers perceive physical activity as important for children's overall health. Nevertheless, we found that Latino FCCH providers in our study appear to have a wide range of concepts of what constitutes physical activity practices for children and reported a range of time in which they regularly implement physical for children in their FCCHs. These findings are consistent with those of previous studies [35, 36] showing a wide range of perceptions, knowledge, and practices related to physical activity among young children. Previous studies [37–39] have documented that caregivers' modeling of physical activity is influential in children's physical activity levels. Providers in our focus groups did not mention the importance of caregivers' physical activity level and modeling; therefore future training resources for promoting physical activity practices in FCCHs should highlight importance of caregiver physical activity level and modeling.

Our findings suggest less variation in providers' beliefs and practices related to screen time. Nearly all providers participating in our study reported believing that children should not be allowed more than one hour of screen time daily. Providers in our study spoke of using screen time (mostly educational TV programs) only during transition times (e.g., at pick up, preparation of lunch, etc.). Previous studies conducted among low-income population have shown high levels of TV-watching by children and adults [40, 41]. It is likely that providers participating in our study have been exposed to education and training and required to comply with regulatory policies that encourage limited use of TV and other screen devices set forth by agencies working with licensed FCCHs.

In agreement with previous studies, our findings revealed barriers to physical activity for children in FCCHs [35, 36] including cold weather and the physical environment of the FCCH that may lack appropriate indoor and outdoor spaces. Many providers in our study live in neighborhoods with small or no yard areas. Some reported financial constraints as limiting configuring indoor space for active play. This finding is consistent with previous studies, including our own [14, 41] with Latino parents, which found housing and neighborhood barriers faced by families living in low-income areas, with limited access to indoor and safe outdoor spaces [14, 34, 40, 41]. This is an important finding, and as suggested by previous studies [35, 36], physical activity interventions targeting family child care homes must be tailored to meet the unique characteristics of this home-based child care environment.

Specific cultural influences related to Latino FCCH providers' beliefs, attitudes, and practices related to nutrition and physical activity were not widely apparent in our study. Although some providers reported serving foods typical to the Latino culture such as rice and beans on a regular basis, it is possible that other cultural influences reported by previous studies conducted among Latino populations such as, consumption of sugar-sweetened beverages and use of TV may be less present in licensed Latino FCCHs due regulatory agency requirements.

Finally, given the pivotal role that parents have in structuring home environment [12], it is important to note that the Latino FCCH providers in our study perceive that parental home environment is lacking in nutrition and physical activity structure. FCCH providers may be well positioned given their daily and close relationship with parents to engage and educate low-income, Latino parents about the importance of establishing a home environment conducive to the development of early healthy behaviors related to children's eating and physical activity. Our findings highlight the important influence and role that Latino FCCH providers can have as a unit of change and promotion of health in low-income, Latino communities. Interventions involving FCCH providers may prove to be an effective way to target low-income minority families for obesity prevention efforts. Given FCCH providers established presence in their communities, they are well positioned to facilitate low-income families' access to evidence-based information in a linguistic and culturally sensitive way. Latino providers have established trusting and respected relationships with Latino parents, which positions their family child care homes as an important venue for the delivery of long-term and sustainable efforts to prevent childhood obesity among at-risk, minority communities. The potential role of minority FCCH providers should be explored in future community-based interventions aimed at promoting healthful family behaviors related to nutrition and physical activity.

Results of this study should be considered in light of some limitations. Findings are based on a nonrandom, purposive, and relatively small sample of low-income, Latino FCCH providers in four selected communities in Massachusetts. Furthermore, FCCH providers recruited to participate in this study could have been those who are more aware and concerned in general with promoting health behaviors among children in their care. Future research can address these limitations by exploring influences on Latino providers' beliefs, attitudes, and practices from other communities across the US. In addition, quantitative research that builds on the qualitative findings reported here is needed to quantify Latino providers' beliefs, attitudes, and practices related to the promotion of healthy eating and physical activity behaviors among Latino preschool children attending FCCHs.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Birth Weight, Current Anthropometric Markers, and High Sensitivity C-Reactive Protein in Brazilian School Children

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Studies have shown associations of birth weight with increased concentrations of high sensitivity C-reactive protein. This study assessed the relationship between birth weight, anthropometric and metabolic parameters during childhood, and high sensitivity C-reactive protein. A total of 612 Brazilian school children aged 5–13 years were included in the study. High sensitivity C-reactive protein was measured by particle-enhanced immunonephelometry. Nutritional status was assessed by body mass index, waist circumference, and skinfolds. Total cholesterol and fractions, triglycerides, and glucose were measured by enzymatic methods. Insulin sensitivity was determined by the homeostasis model assessment method. Statistical analysis included chi-square test, General Linear Model, and General Linear Model for Gamma Distribution. Body mass index, waist circumference, and skinfolds were directly associated with birth weight ($P < 0.001$, $P = 0.001$, and $P = 0.015$, resp.). Large for gestational age children showed higher high sensitivity C-reactive protein levels ($P < 0.001$) than small for gestational age. High birth weight is associated with higher levels of high sensitivity C-reactive protein, body mass index, waist circumference, and skinfolds. Large for gestational age altered high sensitivity C-reactive protein and promoted additional risk factor for atherosclerosis in these school children, independent of current nutritional status.

1. Introduction

Environmental factors acting early in life influence the risk of developing adult cardiovascular disease (CVD). Birth weight and/or infant weight and accelerated weight gain during childhood are associated with an increased risk of these disorders [1]. Recent research has focused on the role of chronic, low-grade inflammatory processes in the pathophysiology of a wide range of chronic degenerative diseases [2, 3]. In particular, elevated concentrations of C-reactive protein (CRP) have been consistently associated with increased risk for cardiovascular disease [4]. Serum CRP levels were a long-term predictor of risk of cardiovascular and noncardiovascular mortality independent of traditional risk factors or other inflammatory markers, such as fibrinogen and leukocyte count [5].

Thus, both high sensitivity C-reactive protein (hs-CRP) and low birth weight have emerged as predictors of CVDs, but the relationship between these two variables is still unclear. Thinness at birth or during infancy and accelerated body mass index (BMI) gain during childhood/adolescence are associated with a proinflammatory/prothrombotic state in adult life. An altered inflammatory state could be one link between small newborn/infant size and adult cardiovascular disease [6].

Study has shown that low birth weight is associated with higher concentrations of hs-CRP in adults [6], but studies in children failed to demonstrate this association. Considering that metabolic changes associated with hs-CRP concentrations increase from childhood to adulthood, cumulative effects along the life course may explain these differences [7].

Therefore, the objective of this study was to further investigate the relationship between hs-CRP and birth weight and other risk factors (obesity, dyslipidemia) for cardiovascular disease in school children in southern Brazil.

2. Patients and Methods

2.1. Design and Location of Study. We conducted a population-based cross-sectional study in the city of Garibaldi, south Brazil. The city has currently 30,165 inhabitants and 21 elementary public schools with a total of 1,464 students 5–10 years old. Data was collected between 2011 and 2012, after approval of the Research Ethics Committee of the Institute of Cardiology of RS. All parents signed an informed consent and all children agreed to participate.

2.2. Population. Sample size was determined according to the study by Rondó et al. (2013) [7], which identified altered hs-CRP levels in 27.7% of Brazilian children aged 5 to 8 years. Considering the total number of students, cluster sampling (clusters = schools), a 95% confidence level, and a 5% error margin, it would be necessary to study 481 children. Exclusion factors were use of medications that could interfere with laboratories results, current infectious diseases or fever, and history.

2.3. Current Anthropometric Parameters. Anthropometric measurements were repeated three times, nonconsecutively, and mean values were used in the analyses. Participants should be barefoot and wearing light clothes (shorts for boys and shorts and t-shirts for girls). Weight was measured using a digital scale (Techline) with a variation of 100 g. For height measurements, children stood in vertical position, with feet parallel and with the heels, shoulders, and buttocks touching the wall, and a stadiometer with accuracy of 0.1 cm was used.

BMI, determined as weight in kilograms divided by height in meters squared, was used to assess the nutritional status, based on the BMI-for-age standards determined by the World Health Organization (WHO) [8] and values ≥+1 were considered overweight [8].

For measurement of the waist circumference (WC), children were placed in standing position, with the abdomen relaxed and arms along the body. The measuring tape was positioned around the natural waist line, in the narrower region between the thorax and the pelvis, at the midpoint between the last rib and the iliac crest, with a firm but not compressive force. The measurement was made at the time of expiration [9]. Body composition was assessed through the sum of the tricipital and subscapular skinfolds.

All measures were performed by a registered dietitian (CB) and two previously trained undergraduate nutrition students.

2.4. Data Related to Child Birth. Parents or caretakers were asked to bring birth registrations on the day of the scheduled interview, for collection of information on birth weight and gestational age at birth. Birth weight was categorized as proposed by the WHO [8], with the following cut-off points: low weight (<2,500 g), insufficient weight (2,500–3,000 g), and adequate weight (3,000–4,000 g).

Birth weight according to gestational age was classified according to the curve developed by Lubchenco et al. (1963) [10]: small for gestational age (SGA) when below the 10th percentile, appropriate for gestational age (AGA) when between the 10th and 90th percentile, and large for gestational age (LGA) when above the 90th percentile.

2.5. Biochemical Parameters. Blood was collected according to the protocol provided by the Brazilian Society of Cardiology [11] and was conducted by a biochemist, during the morning and after the appropriate fasting period (8–12 hs). All children were necessarily accompanied by parents or guardians. About 6 mL of blood were collected by venipuncture in the cubital fossa, using disposable material. The blood samples were stored at -20°C in heparinized vacutainer tubes. Serum levels of total cholesterol (CT), triglycerides (TG), and glucose were determined with an automated enzymatic method. An automated homogeneous assay was used for determination of high density lipoprotein (HDL-c) levels, and insulin was evaluated by chemiluminescence. The low density lipoprotein (LDL-c) level was calculated by the Friedewald formula [12]. hs-C-reactive protein levels were studied by nephelometric high-sensitivity assay. The homeostasis model assessment method for insulin resistance (HOMA-IR) was used for the evaluation of insulin resistance, by multiplying the glycemic index (mmol/L) by the insulin index (μUI/mL), both measured in fasting, and dividing by 22.5 [13].

2.6. Statistical Analyses. The statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS), version 21.0. The chi-square test was used for categorical variables. All data sets were tested for normality with Kolmogorov Smirnov Test. Variables with normal distribution were analyzed with one-way ANOVA, and asymmetric variables were analyzed with Mann-Whitney test. For regression analyses with control of confounding factors, linear models were used for data with normal distribution, and linear models with gamma distribution were used for asymmetric variables. The best adjusted model between all anthropometric variables was verified by the Akaike information criteria. Statistical significance was set at alpha <0.05.

3. Results

A total of 612 school children were evaluated. Of those, 572 presented complete data and were included in this study. Mean age of the participants was 8.6 (±1.46) years, and 51.5% were male. Analysis of maternal age at birth showed that 16.7% of the school children were born to teenage mothers, and 86.1% were Caucasian.

The prevalence of school children with very low and low birth weight was 7.7% and 5.6%, respectively, and 86.8% had adequate birth weight. The frequency of school children born SGA was 2,1%, AGA 79.6% and LGA was 18.2%.

A higher proportion of boys than girls (23.7% versus 12.5%) had LGA ($P < 0.001$). The maternal age and ethnicity

Table 1: Birth weight, maternal characteristics, and gender in Brazilian school children ($n = 612$), 2013.

	Total		SGA birth		AGA birth		LGA birth		P value
	n	%	n	%	n	%	n	%	
Maternal age at child birth									
<20 years	101	16.7	2	2.2	71	78.0	18	19.8	0.92
≥20 years	505	83.3	10	2.2	371	79.8	84	18.1	
Ethnicity									
Other ethnicities	85	13.9	0	0.0	57	79.2	15	20.8	0.35
White	527	86.1	12	2.5	388	79.7	87	17.9	
Gender									
Male	315	51.5	4	1.4	215	74.9	68	23.7	<0.001
Female	297	48.5	8	2.9	230	84.6	34	12.5	

SGA: small for gestational age.
AGA: appropriate for gestational age.
LGA: large for gestational age.

Table 2: Association between birth weight and anthropometric markers, lipid profile, glucose, HOMA-IR index, and hs-CRP in Brazilian school children ($n = 612$), 2013.

	SGA birth			AGA birth			LGA birth			P value
	n	Mean	SD	n	Mean	SD	n	Mean	SD	
Anthropometric parameters										
Body mass index (z-score)	12	−0.6	1.3	444	0.5	1.4	102	0.8	1.3	**<0.001**
Waist circumference (cm)	12	55.8	5.3	441	60.3	8.2	101	63.6	10.5	**<0.001**
Skinfolds (mm)	12	15.3[a]	8.2	444	19.7	11.0	101	20.1	11.9	**0.02**[a]
Blood parameters										
Total cholesterol (mg/dL)	12	161.2	31.4	438	167.0	27.2	100	167.5	24.7	0.82
HDL-cholesterol (mg/dL)	12	51.3	14.2	436	50.3	10.3	101	50.6	10.9	0.97
Triglycerides (mg/dL)	12	109.4	35.7	437	98.4	33.8	101	94.6	28.3	0.26
LDL-cholesterol (mg/dL)	12	88.0	25.0	435	97.2	24.6	100	97.6	23.0	0.59
Glycemia (mg/dL)	12	82.2	6.5	438	82.3	7.8	101	83.0	6.5	0.73
HOMA-IR	12	1.15[b]	0.8–1.5[c]	438	1.0[b]	0.6–1.5[c]	101	0.98[b]	0.7–1.4[c]	**0.03**[a]
Insulin (μ/dL)	12	5.4[b]	4.5–7.1[c]	438	5.0[b]	3.2–7.2[c]	101	4.7[b]	3.4–6.7[c]	0.02[a]
hs-CRP (mg/dL)	12	0.01[b]	0.01-0.02[c]	438	0.01[b]	0.01–0.06[c]	101	0.0[b]	0.01–0.09[c]	**<0.001**[a]

[a]Nonparametric test—General Linear Model—Gamma distribution.
[b]Median.
[c]P25–75.
SGA: small for gestational age.
AGA: appropriate for gestational age.
LGA: large for gestational age.
HDL: high density lipoprotein.
LDL: low density lipoprotein.
HOMA-IR: homeostasis model assessment method for insulin resistance.
hs-CRP: high sensitivity c reactive protein.

did not differ significantly with the hs-CRP (Table 1). The BMI showed higher values of z-score in school children with LGA ($P < 0.001$). The same was observed for the waist circumference and skinfolds ($P < 0.001$ and $P = 0.02$, resp.) (Table 2).

School children with LGA showed higher values of hs-CRP, HOMA-IR, and insulin, in comparison with SGA ($P < 0.001$, $P = 0.03$, and $P = 0.02$, resp.). Other biochemical parameters analyzed showed no statistically significant differences (Table 2).

The association between birth weight and the three anthropometric markers analysed, BMI, WC, and skinfolds, remained statistically significant in the regression model analysis ($P < 0.001$, $P = 0.001$, and $P = 0.015$, resp.). The association between hs-CRP levels and LGA was also present after adjusting for gender, body mass index, waist circumference, and skinfolds ($P < 0.001$) (Table 3).

4. Discussion

The results observed in the evaluation of school children in southern Brazil showed that high birth weight is associated with higher levels of high sensitivity C-reactive protein, body mass index, waist circumference, and skinfolds.

Table 3: Adjusted association between birth weight and anthropometric markers, lipid profile, glucose, HOMA-IR index, and hs-CRP in Brazilian school children ($n = 612$), 2013.

	SGA birth			AGA birth			LGA birth			P value
	n	Mean	SEM	n	Mean	SEM	n	Mean	SEM	
Anthropometric parameters[a]										
Body mass index (z-score)	12	−0.65	0.39	444	0.53	0.06	102	0.88	0.14	**<0.001**[c]
Waist circumference (cm)	12	56.0	2.5	441	60.3	0.41	101	63.4	0.86	**0.001**[c]
Skinfolds (mm)	12	14.6	3.4	444	19.7	0.55	101	22.7	1.17	**0.002**[d]
Blood parameters[b]										
Total cholesterol (mg/dL)	12	162.7	7.7	438	166.6	1.3	100	167.2	2.7	0.85[c]
HDL-cholesterol (mg/dL)	12	51.6	3.0	436	50.3	0.5	101	50.4	1.0	0.92[c]
Triglycerides (mg/dL)	12	112.1	8.8	437	98.4	1.4	101	93.7	3.0	0.10[c]
LDL-cholesterol (mg/dL)	12	88.7	6.9	435	96.8	1.15	100	97.9	2.4	0.45[c]
Glycemia (mg/dL)	12	82.6	2.2	438	83.1	0.4	101	82.4	0.8	0.72[c]
HOMA-IR	12	1.5	0.25	438	1.13	0.03	101	1.12	0.06	0.18[d]
Insulin (μ/dL)	12	7.5	1.18	438	5.4	0.14	101	5.5	0.31	0.14[d]
hs-CRP (mg/dL)	12	0.02	0.01	438	0.12	0.01	101	0.15	0.02	**<0.001**[d]

[a] Adjusted for gender.
[b] Adjusted for gender, body mass index, waist circumference, and skinfolds.
[c] General Linear Model—Normal Distribution.
[d] Nonparametric test—General Linear Model—Gamma distribution.
SEM: Standard Error Mean.
SGA: small for gestational age.
AGA: appropriate for gestational age.
LGA: large for gestational age.
HDL: high density lipoprotein.
LDL: low density lipoprotein.
HOMA-IR: homeostasis model assessment method for insulin resistance.
hs-CRP: high sensitivity c reactive protein.

The prevalence of school children born with LGA was 18.2%, and the prevalence of school children born SGA was 2.1%. Scientific evidences around the world have shown concern with the increasing prevalence of low birth weight, which has been associated with several health complications. However, the present study highlights that high birth weight may also be related to several complications shown by anthropometric, metabolic, inflammatory, and biochemical results, thus contributing to the early development of the cardiovascular risk factors in school children. This represents a new association between birth weight and early outcomes associated with overweight, dyslipidemia, and metabolic and inflammatory changes. Singhal et al. [14] showed that high birth weight, determined by the increase of one standard deviation in the BMI, results in higher values of this anthropometric indicator in adolescence. High birth weight and rapid weight gain in the first 3 months of life contribute to elevating the BMI at 2 years of age, demonstrating the early interaction between high birth weight and childhood overweight [15].

However, the association between birth weight and BMI contradicts considerable evidence that a high birth weight programs less susceptibility rather than greater susceptibility to cardiovascular disease (CVD) risk factors [16, 17]. Previous studies have shown that babies who are born small and then show rapid catch-up growth have in a recent systematic review been shown to be more obese in later life [18]. Some authors consider that catch-up growth in the first few weeks of postnatal life is particularly disadvantageous [19, 20] whereas others suggest that low birth weight children who grow excessively in later childhood are also particularly at risk of later obesity [21]. The prevalence of low birth weight found in our study was similar to that mentioned in national data released by the United Nations [22]. The study "Prematurity and its possible causes" investigated data on low weight of more than 6,000 Brazilian children, concluding that the incidence of about 8% of low birth weight in total births has remained stable since 2000. However, a recent study on children born in 2013 in China showed a prevalence of 1.7% of low birth weight [15]. Ethnic differences, or age of the mother, may have influence on the different prevalence of cases of low birth weight in different countries. In Brazil, low birth weight is more frequent in black mothers (9.4%), followed by white (8.3%) and mulatto mothers (8.2%). The lowest rates were found between Asian and indigenous women: 7.6% and 7.7%, respectively [23]. In the present work, no significant relationship was observed between maternal age or ethnicity and birth weight classification according to gestational age. However, a higher proportion of boys than girls had LGA. In a recent study, no statistically significant difference was observed between the birth weight of boys and girls [15]. It should be noted that the method used for classification of birth weight considered only this variable, whereas in the present study the variable weight at birth was determined according to gestational age, classifying individuals by percentiles.

The analysis of birth weight and metabolic indicators showed higher values of glycaemia, insulin, and HOMA-IR in the children with LGA, but this association was not significant when BMI was considered a controlling factor. Factors related to obesity, such as the accumulation of abdominal fat and hyperinsulinemia, are also associated with the thrombogenic and inflammatory profile. Atherogenic, thrombogenic, and inflammatory metabolic changes contribute to a higher risk of coronary heart disease in obese children and adolescents, with accumulation of fat in the abdominal area [23]. It is known that overweight is an important cause of altered levels of insulin, blood sugar, and consequently HOMA-IR. Genetically determined insulin resistance could result in impaired insulin-mediated growth of fetal muscle, and the continuation of this pattern of body composition would lead to less muscle mass later in life [24].

High levels of inflammatory markers such as IL-6, tumor necrosis factor, and CRP are related to general and abdominal obesity. Children with overweight and obesity have higher concentrations of serum CRP, which supports the hypothesis of a relationship between childhood obesity and the presence of systemic inflammatory substances [25]. Inflammation has been understood to be a key pathogenic mechanism in the initiation and progression of cardiovascular disease (CVD) [26] and great attention has been given to inflammatory markers for their ability to predict CVD risk [3].

Our results showed that levels of hs-CRP in school children at school age are significantly higher in cases of LGA. However, in a cohort study [27], an inverse relationship between CRP and BMI values was found at 2, 11, and 21 years of age. Similarly, no statistically significant association between birth weight and hs-CRP was observed in a study in Brazil with children of 5–8 years of age [28].

Thinness at birth and/or in infancy is associated with higher fibrinogen, hs-CRP in adulthood. Both in-utero influences and greater adiposity due to BMI gain in childhood/adolescence could be implicated consolidating the need to prevent excessive BMI gain in childhood [6].

All anthropometric markers measured in this study (BMI, WC, and skinfolds) were increased in the participants who were LGA when compared to SGA. Similar results were found in the study of Rondó et al. [28], who described a positive association between WC and elevation of hs-CRP levels. Thomas et al. [29] observed a relationship between fatness and higher values of CRP, suggesting that a reduction of body fat can decrease the levels of CRP and thus prevent future cardiovascular events.

Infancy is understood as a critical period for the development of obesity for many reasons, but primarily because infants are experiencing food transitions, establishment of eating habits, and, too often, the early development of excess adiposity. Recently, more evidence has become available regarding the associations of early weight status and rapid growth with obesity and related problems in later life [30, 31]. For instance, Harrington's study showed that more than half of the overweight children aged 2 to 20 years became overweight before the age of two [31].

Body measures, specifically in the pediatric phase, change according to growth and development. The evaluation of the normality of these measures becomes complex but represents an important tool for evaluating the growth and nutritional status of children and adolescents. In this age group, nutritional changes usually reflect on growth, so that anthropometric parameters are important indicators for the assessment of nutritional status [32].

5. Conclusions

High birth weight and/or in infancy is associated with higher levels of high sensitivity C-reactive protein, BMI, WC, and skinfolds. Large for gestational age altered high sensitivity C-reactive protein and promoted additional risk factor for atherosclerosis in these school children, independent of current nutritional status.

Conflict of Interests

No potential conflict of interests relevant to this article was reported.

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Research Article

Prenatal Stress due to a Natural Disaster Predicts Adiposity in Childhood: The Iowa Flood Study

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Prenatal stress can affect lifelong physical growth, including increased obesity risk. However, human studies remain limited. Natural disasters provide models of independent stressors unrelated to confounding maternal characteristics. We assessed degree of objective hardship and subjective distress in women pregnant during severe flooding. At ages 2.5 and 4 years we assessed body mass index (BMI), subscapular plus triceps skinfolds (SS + TR, an index of total adiposity), and SS : TR ratio (an index of central adiposity) in their children ($n = 106$). Hierarchical regressions controlled first for several potential confounds. Controlling for these, flood exposure during early gestation predicted greater BMI increase from age 2.5 to 4, as well as total adiposity at 2.5. Greater maternal hardship and distress due to the floods, as well as other nonflood life events during pregnancy, independently predicted greater increase in total adiposity between 2.5 and 4 years. These results support the hypothesis that prenatal stress increases adiposity beginning in childhood and suggest that early gestation is a sensitive period. Results further highlight the additive effects of maternal objective and subjective stress, life events, and depression, emphasizing the importance of continued studies on multiple, detailed measures of maternal mental health and experience in pregnancy and child growth.

1. Introduction

Researchers and public health officials have long recognized the role of maternal health during pregnancy in shaping the health of the infant. In the last three decades, research in the developmental origins of health and disease has highlighted effects extending well beyond infancy [1, 2]. Children whose mothers had poor nutrition during pregnancy are more likely to be born small and have greater risk for obesity and diabetes, particularly if they have rapid growth in the first weeks [3] or months [4, 5] of life. In addition to the prenatal nutritional environment, prenatal stress is increasingly recognized to contribute to cardiometabolic disease risk [6], including later obesity [7] and features of diabetes [8, 9]. This likely reflects effects of maternal stress hormones which, at high levels, can cross the placental barrier and affect fetal development [10], as well as epigenetic changes in the placenta and fetus [11–13]. In addition to adverse effects on fetal growth, which is an independent risk factor for obesity [14], maternal stress might influence long-term metabolic outcomes through effects on the developing hypothalamic pituitary adrenal axis [12, 15] or on metabolism at the cellular level [16] and thereby increase obesity risk independent of effects on birth weight [17].

Despite this growing body of evidence, studies of the effects of prenatal stress on physical growth in humans remain limited. Danish National Register studies indicated that bereavement due to death of a close relative during or shortly before pregnancy was associated with increased risk of overweight among the women's children from ages 10 to 13 years [18] and in early adulthood [19]. Similarly, results from Project Viva, a prospective cohort study of pregnant women and their children, indicated smaller body size but greater central adiposity at age 3 years in association with antenatal depression [20] and with 2nd trimester maternal corticotropin-releasing hormone (CRH), which provides a marker of fetal glucocorticoid exposure [21]. However, a Danish National Birth Cohort study examining a combined measure of maternal distress in pregnancy, reflecting self-reported anxious, depressive, or stress symptoms, showed no associations with offspring overweight at age 7 [22]. These results highlight some of the difficulties of designing human studies of prenatal stress: effects might differ for stress, anxiety, depression, or hormonal markers of stress. Furthermore, anxiety, depression, and bereavement might be associated with one another and with other maternal characteristics that can influence child development. Finally, the effects of prenatal stress on later growth and development depend on the timing of exposure during gestation [23, 24], but many human studies are not able to evaluate the timing of the stressor with accuracy. Thus, we need more studies examining the effects of independent stressors during pregnancy on body composition in children.

Natural disasters provide excellent opportunities to examine the effects of prenatal stress on childhood outcomes because the stressors are independent of potentially confounding genetic and medical risk factors and are relatively randomly distributed with regard to household and maternal characteristics. Furthermore, because the dates of the events are clearly known, we can identify the timing of stress exposure during pregnancy [25]. Our first prospective longitudinal study of prenatal stress due to a natural disaster, Project Ice Storm, has followed the development of children whose mothers were pregnant during a severe ice storm in 1998. Exposure to the ice storm was associated with shorter length at birth [26] and with measures of physical growth later in childhood. Greater objective hardship due to the storm predicted greater body mass index (BMI) and increased risk of obesity at age 5.5 [27], as well as insulin secretion and BMI in adolescence [28]. However, this study left unanswered questions about the effects of prenatal stress on physical growth in early childhood.

In June 2008, an opportunity to replicate Project Ice Storm arose when the U.S. Midwest experienced its worst flooding in more than 50 years. We recruited women exposed to the floods during pregnancy, assessed their stress levels soon after the floods, and collected anthropometric measurements among their children at ages 2.5 and 4 years. We examined relationships between timing and severity of flood exposure and these body composition measurements.

2. Materials and Methods

All phases of this study were approved by the University of Iowa Institutional Review Board.

2.1. Participants. Immediately following the start of the flooding, we recontacted women enrolled in an existing study of maternal characteristics and pregnancy outcomes at the University of Iowa [29], who had initially been recruited at <20 weeks of gestation from the University of Iowa Hospitals and Clinics. We recruited additional women from three severely flood-affected counties (Linn, Johnson, and Blackhawk). All women were of age 18 or older and English speaking. Of 323 women approached, 268 provided information concerning the flood; 217 were pregnant at the time of the floods.

Families were invited to participate in assessments of children's behavioral, cognitive, and physical outcomes when children were 2.5 and 4 years of age. At age 2.5, 131 families participated in assessments: 27 completed only postal questionnaires and 104 completed face-to-face assessments, when anthropometric measurements were collected. At age 4, 105 families participated in assessments: 24 completed only postal questionnaires and 81 completed face-to-face assessments.

Anthropometric data were missing for some participants, leaving a final sample of 106 women who were exposed to the floods in the 3rd ($n = 34$), 2nd ($n = 41$), or 1st ($n = 31$) trimester and their children (58 boys, 48 girls) who participated in the assessments at age 2.5 only ($n = 29$), age 4 only ($n = 7$), or both ages ($n = 70$).

2.2. Assessments. Anthropometric measurements were collected following standard guidelines [30]. Standing height was measured without shoes to the nearest 0.1 cm and weight to the nearest 0.1 kg for mothers and children. Children's triceps and subscapular skinfolds were measured three times each on the right side of the body using Lange calipers, and the mean of the three measurements was used for analyses.

2.3. Control Variables. At recruitment in 2008, we collected demographic information; maternal medical and obstetric history; and information on smoking (number of cigarettes/day) and alcohol consumption (number of drinks/week) during pregnancy, using telephone interviews and mail questionnaires. Socioeconomic status (SES) was determined based on parental education and occupation status using the Hollingshead Social Position Criteria [31]. Medical and obstetric history variables relevant to the tested outcomes were combined into an obstetric/fetal risk factor variable, which included history of kidney disease; hypertension; anemia; heart disease; seizures; diabetes; HIV; Rh negative status; asthma; sexually transmitted infections; abnormal blood clotting; thyroid disorders; vaginal, cervical, or urinary tract infections; endocrine disorders; abnormal pregnancy weight gain (<4 kg or >18 kg); preeclampsia; or abnormal bleeding during pregnancy.

Twelve months after the flood, we assessed stressful maternal life events (other than the flood) using the Life Experiences Survey (LES) [32], a self-report measure of life changes, such as death of a spouse or a work promotion. Women were instructed to indicate events occurring from the beginning of their 2008 pregnancy up to the present day. Mothers also completed the Inventory of Depression and Anxiety Symptoms (IDAS) [33], a self-report measure of depression and anxiety symptoms.

At the 2.5-year assessments, we collected data on breastfeeding patterns using semistructured interviews, during which women recalled the age and duration of exclusive, predominant, and mixed breastfeeding, as well as the age of introduction of other foods.

2.4. Flood-Related Variables

2.4.1. Objective Hardship. We assessed the severity of flood-related events experienced by participants using a questionnaire that tapped into four categories used in other disaster studies: Threat, Loss, Scope, and Change [34]. Because each natural disaster presents unique experiences, questions must be tailor-made. Our scale included questions specific to the flood, such as days without electricity, damage to the home, and danger due to flood waters. Each dimension was scored on a scale of 0–25 ranging from no exposure to high exposure. A total score (IF100) was calculated by summing the four dimensions using McFarlane's approach [35]. A detailed presentation of the scale is presented elsewhere [36]. In the present sample, scores ranged from 0 to 50 out of a possible 100 points.

2.4.2. Subjective Distress. We assessed women's psychological reaction to the flood using the Impact of Event Scale-Revised (IES-R) [37]. This 22-item scale describes symptoms from 3 categories relevant to posttraumatic stress disorder: intrusions (thoughts and images), hyperarousal, and avoidance. Participants responded on a 5-point Likert scale, from "0-*Not at all*" to "4-*Extremely*," the extent to which each behavior described how they felt over the preceding 7 days. Items were written to reflect symptoms relative to the flood. The total score was used in analyses. In the present sample, scores ranged from 0 to 60 out of a possible 88 points.

2.4.3. Timing of Exposure. The timing of flood exposure during pregnancy was defined as the number of days between June 15, 2008—the peak of the floods—and the infant's due date. Third trimester exposure corresponds to due dates falling between 0 and 93 days following June 15th; 2nd trimester, 94–186 days; and 1st trimester, 187–279 days.

2.5. Outcome Variables. Outcome variables included sex- and age-specific body mass index Z-scores based on Center for Disease Control (CDC) child growth standards [38]; subscapular and triceps skinfold sum (SS + TR), an index of total adiposity [39]; and subscapular to triceps skinfold ratio (SS : TR), an index of central adiposity [39].

2.6. Statistical Analyses. Objective hardship (IF100) and subjective distress (IES-R) scores were right-skewed and were thus log-transformed for analysis. In addition to child sex, eight covariates expected to be potentially related to child outcomes based on the literature reviews were included in analyses: birth weight (g), obstetric/fetal risk score, maternal BMI (measured during the 2.5-year assessments for analyses of child outcomes at age 2.5 and for the difference between ages 2.5 and 4 and measured during the 4-year assessments for analyses of child outcomes at age 4), smoking during pregnancy (per day), breastfeeding duration (months), SES, general depression, and number of life events.

We tested relationships between predictor and outcome variables using hierarchical linear regression. In a series of individual steps, we first entered child sex and control variables, followed by flood variables: exposure timing, objective hardship, and subjective distress. In a second set of models, for analyses of SS + TR and SS : TR, we included child BMI Z-score in the control variables, measured during the 2.5-year assessments for analyses at age 2.5 and for the difference between ages 2.5 and 4 and measured during the 4-year assessments for analyses at age 4. Finally, in a third set of models, we entered interactions after the flood variables, including objective hardship∗sex, subjective distress∗sex, objective hardship∗timing, subject distress∗timing, and objective hardship∗subjective distress. All tests used an *a priori* alpha level of 0.05 (two-sided tests). No measure was taken to correct for multiple testing, as analyses were considered exploratory. Analyses were conducted with SPSS 20.0.

3. Results

3.1. Sample Characteristics and Correlations. Table 1 presents correlations among all study variables as well as their means and standard deviations. Significant correlations suggested that greater objective hardship (IF100) predicted a greater increase in total adiposity between ages 2.5 and 4. Greater subjective maternal distress (IES-R) predicted greater total adiposity at both 2.5 and 4 years. Timing of the floods earlier in gestation predicted greater BMI at age 4, a greater increase in BMI between the two assessments, and greater total adiposity at ages 2.5 and 4 years. Several control variables were also significantly correlated with outcomes. There were no mean differences in predictor variables (flood variables or covariates) among participants who were measured at only age 2.5, only age 4, or both ages (data not shown).

3.2. Multiple Linear Regression Models. Results of regression analyses for each outcome variable are shown in Tables 2–4 and show the progression of variance explained (R^2) with each step.

3.3. Body Mass Index (BMI) Z-Scores (Table 2)

3.3.1. Age 2.5. At entry into the model, birth weight ($P = 0.03$) and maternal BMI ($P = 0.01$) predicted child BMI Z-scores. In the final model, larger birth weight ($P = 0.03$), fewer fetal risk factors ($P = 0.01$), and larger maternal BMI ($P = 0.03$) predicted greater BMI Z-scores. There were no effects of severity of objective hardship or subjective distress due to flood exposure nor of the timing of flood exposure.

3.3.2. Age 4. At entry into the model, fetal risk factors ($P = 0.04$) and maternal BMI ($P < 0.01$) predicted child BMI Z-scores. In the final model, fetal risk factors did not retain significance ($P = 0.56$). Larger maternal BMI ($P < 0.01$)

Table 1: Correlations among predictor and outcome variables and descriptive statistics.

	1	2	3	4	5	6	7	8	9	10	11	12	Mean	SD	n
Predictors															
1 Obj. hardship	1	0.40^{**}	0.18	−0.05	−0.15	0.09	−0.01	0.09	−0.06	−0.09	0.18	0.22^{*}	1.8	0.8	106
2 Subj. distress	0.40^{**}	1	0.00	0.10	−0.02	0.12	0.02	−0.01	-0.26^{*}	-0.21^{*}	0.30^{**}	0.19	1.3	1.1	106
3 Timing	0.18	0.00	1	0.07	−0.02	0.04	−0.08	−0.10	0.10	0.02	−0.17	−0.01	140.5	78.0	106
4 Birth weight	−0.05	0.10	0.07	1	−0.02	0.02	−0.08	−0.05	0.06	0.02	0.09	0.02	3531	469	106
5 Fetal risk	−0.15	−0.02	−0.02	−0.02	1	0.57^{**}	0.53^{**}	0.06	-0.25^{*}	−0.18	−0.11	0.13	0.6	0.9	106
6 Mat. BMI 2.5	0.09	0.12	0.04	0.02	0.57^{**}	1	0.92^{**}	0.00	-0.40^{**}	−0.19	0.06	0.26^{**}	26.5	5.8	99
7 Mat. BMI 4	−0.01	0.02	−0.08	−0.08	0.53^{**}	0.92^{**}	1	0.09	-0.46^{**}	−0.20	0.02	0.27^{*}	27.3	7.3	75
8 Smoking	0.09	−0.01	−0.10	−0.05	0.06	0.00	0.09	1	0.01	−0.14	0.18	0.25^{*}	0.3	1.5	106
9 BF duration	−0.06	-0.26^{*}	0.10	0.06	-0.25^{*}	-0.40^{**}	-0.46^{**}	0.01	1	0.26^{*}	−0.07	−0.03	8.2	7.0	98
10 SES	−0.09	-0.21^{*}	0.02	0.02	−0.18	−0.19	−0.20	−0.14	0.26^{*}	1	−0.16	-0.26^{**}	53.3	9.8	106
Mat. gen. depr.	0.18	0.30^{**}	−0.17	0.09	−0.11	0.06	0.02	0.18	−0.07	−0.16	1	0.42^{**}	33.2	8.2	106
Mat. life events	0.22^{*}	0.19	−0.01	0.02	0.13	0.26^{**}	0.27^{*}	0.25^{*}	−0.03	-0.26^{**}	0.42^{**}	1	3.0	2.1	106
Child outcomes															
BMIZ 2.5	0.02	0.17	−0.05	0.24^{*}	−0.12	0.14	0.31^{*}	0.03	−0.09	−0.09	0.08	−0.01	−0.03	1.00	98
BMIZ 4	−0.15	0.08	-0.24^{*}	0.16	0.20	0.45^{**}	0.51^{**}	−0.03	−0.19	−0.12	0.07	0.14	0.40	1.09	77
BMIZ dif.	0.06	0.01	-0.28^{*}	−0.08	0.34^{**}	0.29^{*}	0.34^{**}	0.29^{*}	−0.10	−0.05	−0.03	0.16	0.38	0.85	69
SS + TR 2.5	0.09	0.10	-0.25^{*}	0.06	−0.12	0.05	0.22	−0.05	−0.10	0.13	0.09	−0.10	13.9	2.7	88
SS + TR 4	0.13	0.26^{*}	-0.26^{*}	0.09	0.08	0.32^{*}	0.42^{**}	0.15	−0.24	−0.22	0.04	0.14	17.2	3.7	62
SS + TR dif.	0.38^{**}	0.42^{**}	−0.18	0.07	0.19	0.28^{*}	0.36^{*}	0.67^{**}	−0.11	−0.16	0.03	0.27	3.3	3.1	52
SS : TR 2.5	0.03	−0.06	0.00	0.00	−0.20	−0.04	−0.01	0.07	0.19	−0.07	−0.07	0.10	0.61	0.17	88
SS : TR 4	−0.11	0.03	−0.13	0.23	−0.08	−0.11	−0.11	0.03	0.15	0.00	0.23	−0.02	0.64	0.22	62
SS : TR dif.	−0.04	0.18	−0.19	0.27	0.02	−0.13	−0.13	0.04	0.11	0.09	0.36^{**}	−0.07	0.06	0.26	52

$^{*}P < 0.05$; $^{**}P < 0.01$. Abbreviations: Obj. hardship: objective hardship; Subj. distr.: subjective distress; Mat.: maternal; BMI: body mass index; BF duration: breastfeeding duration (months); SES: socioeconomic status; gen. depr.: general depression; BMIZ: body mass index Z-Score; Dif.: difference between values at age 2.5 and 4 years; SS: subscapular skinfold; TR: triceps skinfold.

predicted greater BMI Z-scores. There were no effects of the severity or timing of flood exposure.

3.3.3. Difference between Ages 2.5 and 4. At entry into the model, fetal risk factors ($P < 0.01$) and maternal smoking ($P = 0.04$) predicted difference in BMI Z-scores. There were no effects of the severity of hardship or distress due to flood exposure. However, earlier timing of exposure ($P = 0.04$) predicted a greater increase in BMI Z-scores from age 2.5 to 4. In the final model, fetal risk factors ($P = 0.09$) and smoking ($P = 0.08$) did not retain significance, but earlier timing of flood exposure ($P = 0.03$) predicted a greater increase in BMI Z-scores from age 2.5 to 4.

3.4. Total Adiposity (SS + TR) (Table 3)

3.4.1. Age 2.5. There were no effects of covariates or of the severity of objective hardship or subjective distress due to the flood on total adiposity. However, at entry into the model ($P = 0.04$) and in the final model ($P = 0.03$), exposure timing predicted total adiposity at age 2.5: earlier timing of exposure predicted greater adiposity. The effects of exposure timing remained significant in the final model ($P = 0.03$) even when controlling for child BMI Z-score at age 2.5 (full results not shown).

3.4.2. Age 4. At entry into the model, maternal BMI ($P < 0.01$) and smoking ($P < 0.01$) predicted total adiposity. In the final model, fewer fetal risk factors ($P = 0.01$), larger maternal BMI ($P < 0.01$), and more smoking during pregnancy ($P < 0.01$) predicted greater adiposity. There were no effects of the severity or timing of flood exposure on total adiposity at age 4.

3.4.3. Difference between Ages 2.5 and 4. At entry into the model, smoking ($P < 0.01$) predicted the difference in total adiposity between ages 2.5 and 4. In addition, the severity of both objective hardship ($P = 0.02$) and subjective distress ($P = 0.04$) due to the floods predicted the difference in adiposity between ages 2.5 and 4. In the final model, more smoking during pregnancy ($P < 0.01$), a greater number of maternal life events ($P = 0.04$), greater objective hardship due to the flood ($P = 0.03$), and greater subjective distress due to the flood ($P = 0.04$) all predicted a greater increase in total adiposity. The effects of objective hardship and subjective distress remained significant ($P = 0.03$ and $P = 0.04$, resp.)

Table 2: Summary of hierarchical linear regression analyses for body mass index (BMI). Significant effects are indicated in bold.

Predictor variables	Values at entry into the model					Final model		
	R^2	ΔR^2	F	ΔF	Sig. ΔF	Unstand. coeff. (B)	Stand. coeff. (β)	Sig.
Age 2.5								
(Constant)						−2.19		0.10
Sex	0.00	0.00	0.23	0.23	0.63	−0.01	−0.01	0.96
Birth weight	0.05	0.05	2.53	4.81	**0.03**	0.00	0.23	**0.03**
Fetal risk factors	0.07	0.02	2.24	1.63	0.20	−0.39	−0.33	**0.01**
Maternal BMI	0.13	0.06	3.32	6.19	**0.01**	0.05	0.30	**0.03**
Smoking	0.13	0.01	2.76	0.58	0.45	0.06	0.09	0.41
Breastfeeding dur.	0.14	0.00	2.38	0.52	0.47	0.00	−0.01	0.96
Household SES	0.14	0.00	2.08	0.41	0.52	−0.01	−0.08	0.45
Mat. gen. depr.	0.14	0.00	1.80	0.00	0.96	0.00	−0.02	0.86
Mat. life events	0.15	0.00	1.65	0.50	0.48	−0.04	−0.08	0.50
Exposure timing	0.15	0.01	1.53	0.57	0.45	0.00	−0.07	0.49
Obj. hardship	0.15	0.00	1.38	0.03	0.87	−0.08	−0.07	0.56
Subj. distress	0.17	0.01	1.38	1.37	0.25	0.13	0.14	0.25
Age 4								
(Constant)						−3.24		**0.04**
Sex	0.00	0.00	0.06	0.06	0.81	0.01	0.01	0.96
Birth weight	0.03	0.03	0.95	1.84	0.18	0.00	0.16	0.16
Fetal risk factors	0.09	0.06	2.10	4.30	**0.04**	−0.10	−0.07	0.56
Maternal BMI	0.30	0.21	6.76	18.95	<**0.01**	0.11	0.67	<**0.01**
Smoking	0.30	0.00	5.32	0.00	0.99	−0.02	−0.02	0.90
Breastfeeding dur.	0.31	0.01	4.50	0.60	0.44	0.03	0.19	0.14
Household SES	0.31	0.00	3.84	0.19	0.66	0.00	−0.02	0.85
Mat. gen. depr.	0.31	0.00	3.31	0.03	0.86	0.00	0.03	0.83
Mat. life events	0.32	0.01	2.96	0.45	0.50	−0.04	−0.07	0.57
Exposure timing	0.36	0.04	3.17	3.74	0.06	0.00	−0.17	0.13
Obj. hardship	0.39	0.02	3.13	2.15	0.15	−0.29	−0.22	0.07
Subj. distress	0.41	0.03	3.17	2.55	0.12	0.20	0.19	0.12
Difference								
(Constant)						0.13		0.92
Sex	0.00	0.00	0.02	0.02	0.90	0.07	0.04	0.74
Birth weight	0.01	0.01	0.26	0.50	0.48	0.00	0.01	0.93
Fetal risk factors	0.13	0.12	3.18	8.97	<**0.01**	0.26	0.25	0.09
Maternal BMI	0.14	0.01	2.62	0.92	0.34	0.02	0.14	0.37
Smoking	0.20	0.06	3.06	4.28	**0.04**	0.29	0.23	0.08
Breastfeeding dur.	0.20	0.00	2.56	0.25	0.62	0.01	0.10	0.49
Household SES	0.20	0.00	2.16	0.04	0.84	0.00	0.00	0.98
Mat. gen. depr.	0.21	0.01	1.97	0.66	0.42	−0.01	−0.12	0.37
Mat. life events	0.21	0.00	1.73	0.06	0.80	0.03	0.06	0.69
Exposure timing	0.27	0.06	2.09	4.42	**0.04**	0.00	−0.27	**0.03**
Objective hardship	0.28	0.01	1.94	0.58	0.45	0.11	0.11	0.41
Subjective distress	0.28	0.00	1.76	0.17	0.68	−0.05	−0.06	0.68

Abbreviations: BMI: body mass index; Breastfeeding dur.: breastfeeding duration (months); SES: socioeconomic status; Mat.: maternal; Gen. depr.: general depression.

even when controlling for child BMI Z-score at age 2.5 (full results not shown).

3.5. Central Adiposity (SS : TR)

3.5.1. Age 2.5. There were no effects of covariates or of the severity of objective hardship or subjective distress due to the flood on central adiposity at age 2.5 at entry into the model. In the final model, the fetal risk variable was the only predictor of central adiposity: fewer fetal risk factors predicted greater central adiposity ($P = 0.04$). There were no effects of the timing or severity of flood exposure.

3.5.2. Age 4. At entry into the model and in the final model, maternal general depression was the only predictor of central adiposity (at entry, $P = 0.05$; final model, $P = 0.04$).

Table 3: Summary of hierarchical linear regression analyses for total adiposity (SS + TR). Significant effects are indicated in bold.

Predictor variables	Values at entry into model					Final model		
	R^2	ΔR^2	F	ΔF	Sig. ΔF	Unstand. coeff. (B)	Stand. coeff. (β)	Sig.
Age 2.5								
(Constant)						5.73		0.15
Sex	0.03	0.03	2.51	2.51	0.12	0.98	0.18	0.11
Birth weight	0.04	0.01	1.67	0.83	0.36	0.00	0.14	0.21
Fetal risk factors	0.05	0.01	1.47	1.07	0.30	−0.58	−0.19	0.18
Maternal BMI	0.08	0.03	1.80	2.69	0.10	0.10	0.20	0.17
Smoking	0.08	0.00	1.42	0.02	0.90	−0.03	−0.02	0.87
Breastfeeding dur.	0.09	0.01	1.32	0.80	0.37	−0.02	−0.06	0.63
Household SES	0.12	0.03	1.48	2.34	0.13	0.04	0.15	0.22
Mat. gen. depr.	0.13	0.01	1.41	0.94	0.33	0.04	0.11	0.35
Mat. life events	0.14	0.01	1.36	0.91	0.34	−0.15	−0.12	0.37
Exposure timing	0.18	0.05	1.70	4.24	**0.04**	−0.01	−0.25	**0.03**
Objective hardship	0.20	0.02	1.70	1.60	0.21	0.43	0.14	0.28
Subjective distress	0.20	0.00	1.54	0.06	0.80	0.08	0.03	0.80
Age 4								
(Constant)						9.13		0.10
Sex	0.00	0.00	0.02	0.02	0.90	−0.21	−0.03	0.82
Birth weight	0.00	0.00	0.11	0.21	0.65	0.00	0.00	0.98
Fetal risk factors	0.02	0.02	0.33	0.78	0.38	−2.06	−0.43	**0.01**
Maternal BMI	0.24	0.22	3.78	13.85	**<0.01**	0.31	0.61	**<0.01**
Smoking	0.47	0.23	8.29	20.27	**<0.01**	4.80	0.45	**<0.01**
Breastfeeding dur.	0.47	0.00	6.79	0.09	0.76	0.03	0.06	0.67
Household SES	0.47	0.00	5.70	0.02	0.89	0.00	0.01	0.94
Mat. gen. depr.	0.47	0.00	4.89	0.05	0.82	0.01	0.01	0.94
Mat. life events	0.47	0.00	4.28	0.15	0.70	−0.16	−0.07	0.60
Exposure timing	0.48	0.01	3.92	0.84	0.37	−0.01	−0.11	0.36
Objective hardship	0.49	0.00	3.52	0.22	0.64	0.02	0.00	0.97
Subjective distress	0.52	0.03	3.57	2.63	0.11	0.73	0.21	0.11
Difference								
(Constant)						−1.15		0.77
Sex	0.02	0.02	0.99	0.98	0.33	−0.12	−0.02	0.86
Birth weight	0.02	0.00	0.58	0.18	0.67	0.00	0.07	0.47
Fetal risk factors	0.05	0.03	0.89	1.49	0.23	−0.65	−0.16	0.30
Maternal BMI	0.10	0.05	1.29	2.42	0.13	0.07	0.14	0.33
Smoking	0.54	0.44	10.74	43.84	**<0.01**	5.41	0.60	**<0.01**
Breastfeeding dur.	0.54	0.00	8.78	0.06	0.80	0.05	0.11	0.34
Household SES	0.54	0.00	7.38	0.07	0.79	−0.01	−0.02	0.83
Mat. gen. depr.	0.55	0.01	6.45	0.52	0.47	−0.08	−0.19	0.07
Mat. life events	0.57	0.03	6.28	2.77	0.10	0.44	0.23	**0.04**
Exposure timing	0.58	0.00	5.55	0.15	0.70	0.00	−0.08	0.42
Objective hardship	0.63	0.06	6.20	5.96	**0.02**	0.94	0.23	**0.03**
Subjective distress	0.67	0.04	6.54	4.45	**0.04**	0.71	0.23	**0.04**

Abbreviations: BMI: body mass index; Breastfeeding dur.: breastfeeding duration (months); SES: socioeconomic status; Mat.: maternal; Gen. depr.: general depression.

There were no effects of the timing or severity of flood exposure. The effects of maternal depression remained significant in the final model ($P = 0.05$) even when controlling for BMI Z-scores at age 4 (full results not shown).

3.5.3. Difference between Ages 2.5 and 4. At entry into the model, birth weight ($P = 0.05$) and maternal general depression ($P = 0.01$) predicted the difference in central adiposity between ages 2.5 and 4. There were no effects of the timing or severity of flood exposure. In the final model, greater maternal depression predicted greater central adiposity ($P = 0.02$); birth weight did not retain significance ($P = 0.16$). The effects of maternal depression remained significant in the final model ($P = 0.03$) even when controlling for BMI Z-scores at age 2.5 (full results not shown).

There were no effects of interaction terms in any model (results not shown). In all analyses, variance inflation factors

Table 4: Summary of hierarchical linear regression analyses for central adiposity (SS : TR). Significant effects are indicated in bold.

Predictor variables	Values at entry into model					Final model		
	R^2	ΔR^2	F	ΔF	Sig. ΔF	Unstand. coeff. (B)	Stand. coeff. (β)	Sig.
Age 2.5								
(Constant)						0.76		**<0.01**
Sex	0.00	0.00	0.42	0.41	0.52	0.03	0.09	0.42
Birth weight	0.00	0.00	0.21	0.00	0.96	0.00	0.02	0.83
Fetal risk factors	0.04	0.04	1.22	3.24	0.08	−0.06	−0.30	**0.04**
Maternal BMI	0.05	0.01	1.03	0.47	0.50	0.00	0.15	0.34
Smoking	0.06	0.01	1.02	0.98	0.32	0.01	0.12	0.34
Breastfeeding dur.	0.09	0.03	1.28	2.50	0.12	0.00	0.20	0.14
Household SES	0.11	0.02	1.34	1.66	0.20	0.00	−0.17	0.17
Mat. gen. depr.	0.13	0.03	1.50	2.39	0.13	0.00	−0.20	0.10
Mat. life events	0.14	0.01	1.38	0.50	0.48	0.01	0.10	0.46
Exposure timing	0.14	0.00	1.25	0.23	0.63	0.00	−0.05	0.65
Objective hardship	0.14	0.00	1.12	0.00	0.99	0.00	0.00	0.97
Subjective distress	0.14	0.00	1.02	0.01	0.91	0.00	−0.01	0.91
Age 4								
(Constant)						0.00		1.00
Sex	0.01	0.01	0.72	0.72	0.40	0.04	0.08	0.60
Birth weight	0.08	0.07	2.31	3.85	0.06	0.00	0.21	0.17
Fetal risk factors	0.08	0.00	1.52	0.02	0.89	−0.02	−0.08	0.69
Maternal BMI	0.09	0.01	1.21	0.36	0.55	0.00	−0.01	0.96
Smoking	0.11	0.02	1.20	1.14	0.29	0.08	0.11	0.50
Breastfeeding dur.	0.12	0.01	1.08	0.55	0.46	0.00	0.14	0.46
Household SES	0.13	0.00	0.93	0.14	0.71	0.00	0.01	0.95
Mat. gen. depr.	0.20	0.07	1.36	3.93	**0.05**	0.01	0.33	**0.04**
Mat. life events	0.20	0.00	1.20	0.13	0.72	−0.01	−0.06	0.71
Exposure timing	0.23	0.03	1.29	1.85	0.18	0.00	−0.19	0.22
Objective hardship	0.24	0.00	1.17	0.23	0.63	−0.02	−0.06	0.72
Subjective distress	0.24	0.00	1.06	0.13	0.72	−0.01	−0.06	0.72
Difference								
(Constant)						−0.60		0.19
Sex	0.00	0.00	0.08	0.08	0.78	0.02	0.03	0.81
Birth weight	0.07	0.07	1.98	3.89	**0.05**	0.00	0.20	0.16
Fetal risk factors	0.08	0.00	1.36	0.18	0.67	0.10	0.29	0.19
Maternal BMI	0.11	0.03	1.48	1.79	0.19	−0.01	−0.24	0.26
Smoking	0.11	0.00	1.16	0.00	1.00	−0.12	−0.16	0.35
Breastfeeding dur.	0.12	0.00	0.98	0.15	0.70	0.01	0.15	0.36
Household SES	0.12	0.00	0.82	0.01	0.94	0.00	0.05	0.73
Mat. gen. depr.	0.24	0.12	1.68	6.94	**0.01**	0.01	0.37	**0.02**
Mat. life events	0.25	0.01	1.54	0.53	0.47	−0.02	−0.12	0.45
Exposure timing	0.30	0.06	1.80	3.36	0.07	0.00	−0.27	0.07
Objective hardship	0.31	0.00	1.61	0.16	0.69	0.01	0.03	0.82
Subjective distress	0.33	0.03	1.64	1.61	0.21	0.05	0.20	0.21

Abbreviations: BMI: body mass index; Breastfeeding dur.: breastfeeding duration (months); SES: socioeconomic status; Mat.: maternal; Gen. depr.: general depression.

(VIF) were low (less than 2.8) indicating that results were not affected by multicollinearity among variables.

4. Discussion

Our results indicate that exposure to a natural disaster during early gestation predicts greater total adiposity at age 2.5 and a greater increase in BMI Z-scores from age 2.5 to 4. These results suggest that early pregnancy is a sensitive period for the effects of prenatal stress on childhood growth. Furthermore, prenatal objective hardship and subjective distress exposure significantly and independently predicted a greater increase in total adiposity from age 2.5 to 4 years; a greater number of stressful maternal life events (other than the flood) before and during pregnancy predicted this increase independently of the flood variables. Timing of flood exposure in pregnancy, objective hardship, and subjective distress together increased variance explained by up to 10% over and above that explained by covariates. This supports other studies suggesting that prenatal stress exposure can increase adiposity. Furthermore, our results highlight that effects are evident even in early childhood, which might be a particularly sensitive period for the development of obesity in adulthood [40].

As noted above, the effects of prenatal stress on later growth outcomes might reflect effects on central regulators of metabolism or metabolism at the cellular level, as well as through adverse effects on early growth [17]. The effects of stress exposure in our study persisted even after controlling for birth weight, which supports effects of prenatal stress on central regulators of growth and metabolism rather than through early growth patterns alone.

We observed no effects of flood exposure on central adiposity (SS : TR). However, maternal general depression predicted greater central adiposity at age 4 and a greater increase from age 2.5 to 4. This supports results from Project Viva indicating that antenatal depression predicts greater central adiposity (SS : TR) at age 3 years [20], as well as studies indicating that greater maternal depressive symptoms predict greater risk of overweight in children aged 6–24 months [41]. Maternal depressive symptoms are often associated with adverse maternal health behaviors such as poor diet and exercise patterns, as well as adverse infant and child feeding patterns [41, 42].

Whereas our studies analyze depression at different time points and the mechanisms underlying the effects of prenatal depression are likely to differ from those of postpartum depression, they highlight the importance of maternal depression on adiposity in infancy and the need to distinguish between maternal stress, depression, anxiety, and other measures of maternal mental health in analyses. Differing physiological responses to stress, anxiety, and depression likely result in different mechanistic pathways underlying the effects of each factor on child outcomes [43]; a failure to distinguish between different measures of maternal mental health might obscure effects on child development.

4.1. Strengths and Limitations. Our study is limited by the relatively small sample size for some outcomes, which reduces statistical power and limits the analyses we can conduct. Furthermore, parental body size is a major predictor of children's body size. Although we were able to control for maternal BMI, we do not have anthropometric measurements for most of the children's fathers. However, since fathers' BMI is unlikely to be related to the timing or severity of flood exposure, it is unlikely that this introduces systematic bias into our analyses.

The independent nature of the stressor is the major strength of our study. Flood exposure is unlikely to be related to potentially confounding genetic or socioeconomic characteristics that might affect childhood body composition; for example, we found low correlation between objective hardship (IF100) and SES ($r < 0.20$) in the full sample. We were also able, unlike most studies, to tease apart the relative effects of maternal objective hardship and maternal distress to determine their relative effects. The prospective nature of the study is another strength. Our assessments included the measurement of many household and maternal characteristics that might act as confounders. The persistence of the effects of flood exposure, despite the inclusion of these covariates in all analyses, highlights that prenatal stress can independently affect body composition in childhood. Furthermore, these analyses extended results on the effects of maternal general depression on central adiposity, highlighting differences between the effects of maternal stress and maternal depression on childhood body composition and the need for further research.

5. Conclusions

Research on the developmental origins of health and disease, originally focused on poor maternal nutrition and later cardiometabolic diseases, now highlights that stress during pregnancy is also important in physical growth patterns and obesity risk [9]. Using the Iowa floods as a stressor, we show that exposure in early pregnancy and both objective and subjective stress are associated with greater adiposity in early childhood and a greater increase with age. With a strong body of the literature now supporting these relationships, we must begin to more precisely differentiate between effects of different aspects of maternal mental health on children's development. This research will complement mechanistic research on epigenetic pathways underlying the effects of maternal stress on children's development [44], with the ultimate goal of improving women's and children's health.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Early Life Cognitive Abilities and Body Weight: Cross-Sectional Study of the Association of Inhibitory Control, Cognitive Flexibility, and Sustained Attention with BMI Percentiles in Primary School Children

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The objective of this study was to investigate the association of different cognitive abilities with children's body weight adjusted for further weight influencing sociodemographic, family, and lifestyle factors. Cross-sectional data of 498 primary school children (7.0 ± 0.6 years; 49.8% boys) participating in a health promotion programme in southwest Germany were used. Children performed a computer-based test battery (KiTAP) including an inhibitory control task (Go-Nogo paradigm), a cognitive flexibility task, and a sustained attention task. Height and weight were measured in a standardized manner and converted to BMI percentiles based on national standards. Sociodemographic features (migration background and parental education), family characteristics (parental body weight), and children's lifestyle (TV consumption, physical activity, consumption of sugar-sweetened beverages and breakfast habits) were assessed via parental questionnaire. A hierarchical regression analysis revealed inhibitory control and cognitive flexibility to be significant cognitive predictors for children's body weight. There was no association concerning sustained attention. The findings suggest that especially cognitive abilities known as executive functions (inhibitory control and cognitive flexibility) are associated with children's body weight. Future longitudinal and intervention studies are necessary to investigate the directionality of the association and the potential of integrating cognitive training in obesity prevention strategies. This trial is registered with ClinicalTrials.gov DRKS00000494.

1. Introduction

The dramatically increased prevalence of childhood obesity in industrialised nations has been declared as a major topic of public health in the recent decade [1, 2]. In Germany, 14.8% of children aged 2 to 17 years are overweight or obese [3]. An increase of overweight and obesity is particularly evident at the age of school entry, between 5 and 8 years [3, 4]. Given the significant adverse biopsychosocial consequences of paediatric overweight, its relatively stable course, and the enormous economic costs to the healthcare system, effective prevention strategies are needed [1, 5–8]. It is therefore important to better understand correlates of paediatric overweight and to identify risk factors. Besides a genetic predisposition, increased body weight is influenced by certain behavioural and lifestyle factors such as unfavourable dietary habits, for example, high consumption of sugar-sweetened beverages or skipping breakfast, low levels of physical activity, and preference of sedentary activities, for example, screen media use [9–12]. Furthermore, cultural and family characteristics such as migration background, low socioeconomic position, low parental education, and parental obesity are associated with childhood overweight [3, 11, 13, 14].

Additionally, there is a growing body of evidence suggesting an association between increased body weight and altered cognitive functioning in children. Overweight children show, for example, worse school performance compared to their normal-weight counterparts [15–17]. Moreover, a negative association between obesity and executive functions has been reported [18]. Executive functions are defined as higher-order control processes of the cognitive system that are related to self-regulation and underlie goal-directed and adaptive behaviour [19, 20]. These processes have already been positively related to social and emotional skills, school success, mental and physical health, and social status in adulthood [20, 21]. Different components of executive functions such as inhibitory control (the ability to withhold inappropriate actions) or cognitive flexibility (the ability to adjust to changed circumstances or demands) are usually distinguished [20]. Regarding the association between obesity and executive functions studies have mainly focussed on inhibitory control which is significantly related to body mass index in children and adolescents [18, 22, 23]. Concerning other executive functions (e.g., cognitive flexibility) or further cognitive domains (e.g., attention, memory, and general cognitive function), however, findings are scarce and inconsistent [18, 24, 25].

Assuming an association between children's body weight and cognitive functioning one possible underlying mechanism may be that certain cognitive abilities play a role in learning, adopting, and maintaining health behaviour [26, 27]. As previously mentioned executive functions and most of all the inhibitory components are related to cognitive self-regulation and to disciplined behaviour [20]. In the context of paediatric obesity inhibitory control may be important for young children to regulate their physical activity level and their food intake in terms of appreciating rules from parents or teachers, resisting temptations (e.g., consumption of sweets when not allowed and watching TV or video games when otherwise engaged), controlling distracting thoughts and negative emotional states which may increase appetite, and staying focused on activities such as playing games. Cognitive flexibility may be critical for children when trying out new behaviour and dealing with changes, barriers, or different settings throughout their day and when deliberate attention control (focusing and switching) is necessary. Appreciating healthier food and beverages and active ways of transport when introduced by caregivers, coping with school entry and the related changes, switching between sedentary activities such as homework and active play, and finding ways of being physically active despite bad weather or without any toys may be a few examples. Besides these control functions, further abilities such as sustained attention may play a role in terms of maintaining the focus of attention on specific activities over a certain period of time. Thus, it is important for children not only to cope with immediate distractions, changes, and temptations, but also to stay focused in the long run.

However, the small body of literature regarding childhood and especially early school age can be criticised. Most studies focused only on older children or adolescents. Selectivity, small size of study samples, and the use of self-reporting measures further limit validity of research results. Moreover, researchers addressing paediatric obesity always emphasise the importance of controlling for social factors such as parental income or education [15]. The objective of the present study, therefore, was to investigate the association between different cognitive abilities (inhibitory control, cognitive flexibility, and sustained attention) and body weight in a large nonclinical sample of primary school children. To consider the outlined methodical issues objective standardised tests and assessment methods were used and potentially confounding factors including sociodemographic features, family, and lifestyle were controlled.

2. Materials and Methods

2.1. Overview. In the context of a large evaluation study of a school-based health promotion programme in southwest Germany (the Baden-Württemberg Study) cognitive, anthropometric, sociodemographic, and behavioural data of primary school children were collected. The Baden-Württemberg Study was approved by the institutional ethics committee and is registered at the German Clinical Trials Register (DRKS00000494). Teachers of school classes in the federal state of Baden-Württemberg volunteered to participate in the study and written informed consent was obtained from parents prior to data collection. The Baden-Württemberg Study is a longitudinal study and is designed as a randomised controlled trial. A detailed description of the study has been published by Dreyhaupt et al. [28]. For the present analysis only baseline data of the control and intervention group were used. Baseline assessment took place in autumn 2010 (within a 3-month period from the end of summer vacation in September to the beginning of autumn vacation in November). During this time a research group from the University of Ulm visited the participating school classes (one or two classes each day). Thus, all measurements were performed on-site at school during one school day. On the day of a school visit, children were assigned to small groups based on gender and class to perform the different measurements (e.g., cognitive testing and anthropometric measurement). To obtain information about sociodemographic and lifestyle characteristics a parental questionnaire was issued directly after the measuring period (November 2010) and returned within six weeks.

2.2. Participants. The total sample of the Baden-Württemberg Study consisted of $n = 1944$ children from ethnically and socioeconomically diverse primary schools in the federal state of Baden-Württemberg, Germany. Primary school classes were recruited using a number of different public relations activities such as written information for schools, education and health authorities, adverts in training catalogues for teachers, informative events, or participation at pedagogic trade shows. For logistical reasons (distances between schools, scope of measurements of the Baden-Württemberg Study, and technical equipment) cognitive testing was only carried out in the southern part of Baden-Württemberg at a convenient distance of the research centre in Ulm. Furthermore, children who were absent on the day of school visit were not retested. Cognitive data collection took place in a subsample of $n = 513$ children. After exclusion of $n = 15$ children due to motor impairment, colour blindness, or lack of compliance the sample for the present analysis amounts to $n = 498$ participants. Children attended either

1st grade (57.0%) or 2nd grade and averaged 7.0 ± 0.6 years of age (range 5–9); 49.8% were boys.

Sample size for each cognitive subtest varies due to further missing or invalid data: $n = 479$ children provided valid data for inhibitory control, $n = 445$ for cognitive flexibility, and $n = 466$ for sustained attention. Reasons for further subtest dropouts were, for instance, time restriction at school and lack of comprehension or compliance or implausible data concerning only one subtest. Anthropometric data was available for $n = 496$, and the parental questionnaire was filled out for $n = 441$ children. Complete data including all cognitive measures, anthropometric measures, and parental questionnaire was available for $n = 297$. Figure 1 provides an overview of the sample and subsample selection.

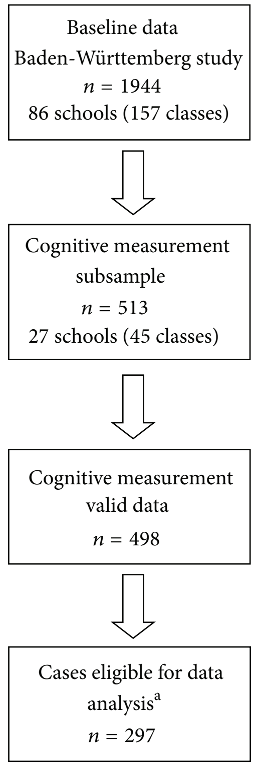

Figure 1: Overview of sample size. [a]Cases with complete data on cognitive, anthropometric, sociodemographic, family, and lifestyle variables were considered eligible for analysis.

2.3. Cognitive Measures. Cognitive abilities were assessed using the computer-based test battery of attention for children (KiTAP) [29]. The KiTAP is validated for children aged 6 to 10 years and consists of a broad range of nonverbal subtests measuring different basal as well as higher-order components of the cognitive system (attention and executive functioning). Each component can be assessed separately. To ensure optimal motivation and compliance all subtests are designed in the form of short games with an enchanted castle theme. This allows the KiTAP to be particularly accessible to young children in comparison to other known test batteries based on more abstract stimuli. Furthermore, a computer-based test was preferable to a paper pencil test as preliminary trials demonstrated that children just entering school had difficulties in turning pages and handling a pencil. Due to the child-friendly character, the feasibility in the school and group setting, and the possibility to measure differentially cognitive functioning (including executive control components) the KiTAP constituted a suitable assessment tool for the present study purposes. In terms of validity the test battery has been especially used in neuropsychological and other paediatric researches [30–32] as well as in research with healthy children and in cross-cultural studies [33, 34]. Significant correlations with school outcomes [34], intellectual abilities [32], and behavioural questionnaires [35] could be found. Factorial analysis confirmed the construct validity [29], and group comparisons (e.g., children with versus without attention deficit hyperactivity disorder) demonstrated criterion validity [30]. The reliability of the test battery can be considered as satisfactory [29].

Three subtests of the KiTAP were administered: an inhibitory control task (Go-Nogo paradigm), a cognitive flexibility task, and a sustained attention task. For each task number of errors (incorrect response to a noncritical stimulus), number of omissions (missed response to a critical stimulus), and reaction time (milliseconds in medians) were recorded. For statistical analysis and to overcome the right skewed distributions of errors and omissions total scores were calculated for each subtest based on the key parameters recommended in the test manual.

(1) Inhibitory Control. The Go/Nogo task examined the ability to respond as quickly as possible to a certain critical stimulus by pressing a button and to withhold the response when another noncritical stimulus emerged. The task lasted 3 minutes. Key parameters were errors and reaction time. Errors could range from 0 to 20 and reaction time from 0 ms to 2700 ms (maximum time interval between two stimuli). The total score was calculated as follows:

$$\text{Total score} = \text{errors standard scores} - \text{reaction time standard scores}. \quad (1)$$

To improve interpretability the score was reversed with a positive total score indicating an overly high inhibitory control (low number of errors and slow reflexive reactions) and a negative score indicating low inhibitory control (high number of errors and fast impulsive reactions). A score around 0 represented an average inhibitory ability.

(2) Cognitive Flexibility. The task examined the ability to deliberately control the attention focus and to adapt responses to changing conditions as quickly as possible. Children had to consider different features simultaneously (colour and location of the stimulus), to switch their attention continuously between these features, and to react appropriately according to the target feature in each trial. In detail, two stimuli in two different colours were presented simultaneously on the right and the left sides of the screen. Children had to press one out of two buttons (left button for the left side or right button for the right side) depending on the colour of the stimuli in an alternate sequence (colour A, colour B, colour

A, colour B,...). On each trial, the stimulus with the target colour could be presented on the same side of the screen as before or on the other side; thus, children had to change their response behaviour or not. Duration of the whole task varied depending on reaction times (approximately 3 minutes). Key parameters were errors and reaction time. Errors could range from 0 to 50 and reaction time from 0 ms to 60000 ms (maximum time interval between two stimuli if no reaction occurred). Contrary to the other subtests, a total score was automatically computed by the KiTAP based on standardised number of errors and reaction time [29]. A positive score represented overly high flexibility (low number of errors and fast reactions) and a negative score low flexibility (high number of errors and slow reactions). A score around 0 represented average cognitive flexibility.

(3) Sustained Attention. The task examined the ability to maintain attention over an extended period of time (10 minutes). During this time children had to compare subsequent stimuli in terms of a specific feature (colour) and to determine whether two stimuli were matching. Key parameters were errors (two stimuli incorrectly indicated as matching) and omissions (two stimuli incorrectly indicated as nonmatching). Errors could range from 0 to 250 and omissions from 0 to 50. The total score represented the number of correct responses and was calculated as follows:

$$\begin{aligned}\text{Total score}&\\ &= \text{total number of stimuli}\\ &\quad - (\text{number of errors} + \text{number of omissions}).\end{aligned} \tag{2}$$

To consider the different number of errors and omissions possible (250 versus 50) the number of errors was relativised (divided by 5):

$$\begin{aligned}\text{Total score}&\\ &= 100 - \left(\frac{\text{number of errors}}{5} + \text{number of omissions}\right).\end{aligned} \tag{3}$$

Thus, the total score ranged from 0 to 100 with a high total score indicating high sustained attention and a low score indicating low sustained attention. A score around 0 represented no sustained attention at all.

Procedure. On the day of a school visit the cognitive tests were administered during the first school hours. Cognitive testing took place in one or two separate quiet classrooms and was carried out by trained examiners using laptops (screen size: 15 inches). As previously mentioned children performed the tests in small groups (up to 8 children). Per group 4 examiners supported and supervised the children (with a maximum of 2 children per examiner). While one testing session took place, which lasted in total 30 minutes, the other groups were assigned either to anthropometric measurement or to other parts of the Baden-Württemberg Study. The subtests of the KiTAP were administered in a fixed order and instructions were given in a standardised manner. Comprehension and willingness of the children were assured by short preceding practice trials according to the test manual. These practice trials could be repeated if necessary—especially the cognitive flexibility task required several preceding trials. The main testing started when it was clear that each child of the group understood the instructions. When the examiner was sure that a child was not able to perform a task, lack of comprehension was documented. The main testing was administered once. Further irregular and disruptive behaviour was documented and later considered during data preparation. Children who were absent on the day of testing were excluded from the analysis as there was no repetition of the testing at a later point in time.

2.4. Anthropometric Measures. Anthropometric measurement took place in a separate room provided by the teacher. Gender segregation of the groups was considered. Body height and weight of the children were taken by trained staff according to the guidelines of the International Society for the Advancement of Kinanthropometry (ISAK) [36]. Height was measured using a portable stadiometer (Seca model 217, Seca, Germany), without wearing shoes, with an accuracy of 0.1 cm. Weight was measured using a calibrated electronic scale (Seca model 862, Seca, Germany), wearing underwear, with an accuracy of 0.05 kg. Children's body mass index (BMI) was calculated as weight divided by height squared (kg/m^2) and converted to BMI percentiles using national age- and sex-specific reference data [37]. To allow international comparisons, weight status was also calculated according to international reference data [38].

2.5. Parental Questionnaire. Sociodemographic data, body weight of parents, and different lifestyle factors of children were assessed via parental questionnaire. Parent education was assigned to the respective level according to the CASMIN classification [39]. The CASMIN (Comparative Analysis of Social Mobility in Industrial Nations) is the most widely used international instrument to classify education considering length, quality, and value of general education as well as vocationally oriented schooling or training. The classification distinguishes primary, secondary, and tertiary education levels. In the present study parent education was determined as the highest level of two parents or the level of a single parent who cares for the child. Due to the small number of cases with primary education level (1.0%) parent education was dichotomised with primary and secondary education levels in one group and tertiary education level in another. Migration background was defined as at least one parent born abroad or at least one parent mainly having spoken a foreign language with the child during its first years of life. Self-reported parental height and weight were used to calculate BMI of mothers and fathers (kg/m^2). Concerning children's lifestyle, TV consumption, physical activity, consumption of sugar-sweetened beverages, and breakfast habits were assessed. The mean time spent watching television per day was rated on a 7-point Likert scale ("never" to "more than 4 hours"). As the American Academy of Paediatrics [40] recommends less than 1-2 hours of total screen time per day, TV consumption was dichotomised using a cut-off point at 1 hour. Further, parents were asked on how many days per week their child was engaging in at least 60 minutes of moderate to vigorous physical activity (range 0 to 7 days) and how often their child was consuming sugar-sweetened beverages (6-point Likert scale: "never" to "more than once per day"). The frequency of having breakfast prior to going to school was rated on a 4-point Likert scale and, for statistical analysis, dichotomised as "never"/"rarely" versus "often"/"always."

2.6. Statistical Methods. To determine the additional predictive value of each of the three cognitive variables on children's body weight (BMI percentiles) hierarchical multiple linear regression analysis was performed. First, a basic model (model 1) was established which included parent education, migration background, BMI of mother and father, children's TV consumption, physical activity, consumption of sugar-sweetened beverages, and breakfast habits. In the next steps inhibitory control, cognitive flexibility, and sustained attention were added successively as predictors (models 2 to 4). Statistical analysis was carried out using SPSS 19 and statistical significance was set at $\alpha = 0.05$. As missing data may have had an impact on the results, differences between the samples and subsamples (the Baden-Württemberg Study sample, $n = 1944$, the cognitive subsample, $n = 498$, and the final sample with complete and valid data, $n = 297$) were analysed using t-test for continuous data and Fisher's exact test for categorical data.

3. Results

3.1. Descriptive Characteristics. Sociodemographic, lifestyle, and weight group characteristics of the different samples are shown in Table 1. In the cognitive subsample ($n = 498$) average BMI percentile of children was 48.21 ± 26.92, and 8.4% were classified as overweight or obese and 7.3% were classified as underweight according to national standards [37]. The prevalence for overweight and for underweight was slightly higher according to international cut-off points [38] (Table 1). Parental BMI averaged 23.86 ± 4.47 (mothers) and 27.90 ± 3.93 (fathers), respectively. Means and standard deviations for all cognitive subtests (total scores, number of errors, number of omissions, and reaction time) are illustrated in Table 2.

3.2. Prediction of Body Weight. To determine whether different cognitive abilities are associated with children's body weight hierarchical regression analysis was conducted. Results are presented in Table 3. First, model 1 revealed migration background, body weight of mother, and body weight of father as significant predictors of children's body weight. No relationship between parental education or the different lifestyle factors and children's body weight was found. As it is shown in models 2 to 4 inhibitory control and cognitive flexibility were significant cognitive predictors over and above all other variables whereas sustained attention did not significantly contribute to the prediction. Inhibitory control and cognitive flexibility together explained an additional amount of 4.5% of variance in the criterion.

3.3. Missing Data. Children of the cognitive subsample ($n = 498$) differed from children of the total study population in terms of migration background and father's BMI. A significantly higher percentage of migration background ($P = 0.022$) and a significantly lower father's BMI ($P = 0.001$) were found in children who performed the KiTAP compared to those who did not. There were no significant differences concerning age, sex, BMI percentiles, weight group, TV consumption, physical activity, consumption of sugar-sweetened beverages, breakfast habits, parental education, and mother's BMI. Children of the final subsample with complete data ($n = 297$) differed significantly from children of the total study population in terms of BMI percentiles, parental education, consumption of sugar-sweetened beverages, and father's BMI. Lower BMI percentiles ($P = 0.008$), a higher percentage of tertiary parental education level ($P = 0.009$), a lower percentage of soft drink consumption ($P = 0.031$), and a lower father's BMI ($P = 0.000$) were found in children with complete data compared to those without. There were no significant differences concerning any other variable. Although the percentage of migration background was increased in the cognitive subsample, more children with migration background dropped out in the further data process. Thus, the final subsample did not differ anymore from the total study sample in this respect.

4. Discussion

The present study examined the association between different cognitive abilities and body weight in primary school children. The findings suggest that especially cognitive abilities known as executive functions such as inhibitory control and cognitive flexibility are associated with children's body weight. In the past decade particularly the influence of inhibitory control was investigated in children and adolescents using a variety of assessment tools [18]. Methods ranged from behaviour questionnaires, ratings, and self-reports to different tasks and computerised tests (e.g., Stroop test, Go-Nogo task, and delay-of-gratification task). In line with the results reported here all studies showed a significant relationship between body weight and inhibitory control in that a higher body weight was associated with poorer inhibition performance. Additionally, a few longitudinal studies indicated that inhibitory control at a younger age can predict children's BMI at an older age [18, 22, 41]. Group analyses revealed less inhibitory control in overweight adolescents compared to their normal weight peers [18, 42]. Pauli-Pott et al. [23] further pointed out a significant interaction with age and assumed that there might be an especially important developmental period at early school age when inhibitory control is particularly important for self-regulation.

Few studies can be found examining the association between cognitive flexibility and body weight. Cserjési et al. [24], for example, found a significant negative correlation in adolescent boys, and obese boys significantly performed

Table 1: Descriptive characteristics of the Baden-Württemberg Study sample and the KiTAP subsamples.

	Baden-Württemberg Study sample (n = 1944)	Missing values	Cognitive subsample (n = 498)	Missing values	Final subsample[a] (n = 297)
Child characteristics					
Age, m (sd)	7.1 (0.6)	0	7.0 (0.6)	0	7.1 (0.6)
Female, n (%)	949 (48.8)	0	250 (50.2)	0	141 (47.5)
BMI percentiles, m (sd)	49.0 (27.9)	51	48.2 (26.9)	2	45.2 (26.3)
Weight group, national reference data, n (%) [37]					
Underweight (<10 BMI percentile)	148 (7.8)		36 (7.3)		25 (8.4)
Overweight (>90 and ≤97 BMI percentile)	108 (5.7)	51	25 (5.0)	2	14 (4.7)
Obese (>97 BMI percentile)	82 (4.3)		17 (3.4)		6 (2.0)
Weight group, international reference data, n (%) [38]					
Underweight	78 (4.0)		50 (10.0)		35 (11.8)
Overweight	190 (10.0)		46 (9.2)		22 (7.4)
Obese	74 (3.9)		15 (3.0)		4 (1.3)
TV consumption > 60 minutes/day, n (%)	242 (14.3)	254	65 (14.9)	61	37 (12.5)
Days/week with at least 60 minutes MVPA, m (sd)	2.7 (1.7)	321	2.8 (1.7)	81	2.8 (1.7)
SSB consumption > once/week, n (%)	416 (24.4)	242	95 (21.6)	58	58 (19.5)
Never/rarely having breakfast, n (%)	223 (13.0)	237	60 (13.7)	58	35 (11.8)
Parental characteristics					
Tertiary parent education level, n (%)	522 (32.2)	324	148 (35.4)	80	115 (38.7)
Migration background, n (%)	525 (31.9)	298	156 (36.4)	70	97 (32.7)
Mother's BMI	24.1 (4.5)	361	23.9 (4.5)	89	24.1 (4.8)
Father's BMI	28.5 (4.1)	481	27.9 (3.9)	121	27.8 (4.0)

Note. [a]Cases with complete data on cognitive, anthropometric, sociodemographic, family, and lifestyle variables. MVPA = moderate to vigorous physical activity. SSB = sugar-sweetened beverages.

Table 2: Mean, standard deviation, and range for cognitive test scores.

	M	SD	Minimum	Maximum	n
Inhibitory control					
Total score	−0.01	1.68	−5.48	4.51	
Number of errors	5.28	3.26	0	15	479
Reaction time (ms)	511.14	76.34	298.00	778.00	
Cognitive flexibility					
Total score	−0.60	9.56	−30.40	22.62	
Number of errors	6.42	3.73	0	16	445
Reaction time (ms)	1261.66	305.14	445.00	2290.00	
Sustained attention					
Total score	82.74	8.86	60.60	100.00	
Number of errors	16.26	16.69	0	72	466
Number of omissions	14.00	7.87	0	37	

Note. ms = millisecond.

worse than their healthy weight counterparts. Verdejo-García et al. [42] used a whole battery of executive functioning tests including response inhibition and flexibility. Similarly, the authors reported significant group differences in the flexibility task and a significant relationship between BMI and flexibility. These findings are supported by further studies focusing all mainly on adolescents [43, 44], whereas Gunstad et al. [25, 45] demonstrated a link between cognitive flexibility (switching-of-attention task) and body weight only in adults but neither in children nor in adolescents. The results reported here conform to most of the existing research literatures even though these studies have been conducted

Table 3: Hierarchical multiple regression model predicting children's body weight from parental, behavioural, and cognitive variables.

Predictors	BMI percentiles Model 1	Model 2	Model 3	Model 4	
	B	B	B	B	95 % CI
Parent education	−4.61	−4.00	−3.91	−4.33	[−10.44, 1.77]
Migration background	7.32*	6.68*	6.87*	6.61*	[0.26, 12.97]
BMI of mother	1.22***	1.13***	1.18***	1.20***	[0.59, 1.81]
BMI of father	1.15**	1.20**	1.13**	1.11**	[0.37, 1.86]
TV consumption	−0.58	−1.99	−2.52	−2.53	[−11.70, 6.64]
Physical activity	1.4	1.18	0.99	0.94	[−0.78, 2.65]
SSB consumption	−2.31	−2.37	−2.39	−2.44	[−6.07, 1.19]
Breakfast habits	4.69	5.05	6.67	6.53	[−2.50, 15.55]
Inhibitory control		−1.98*	−1.94*	−1.94*	[−3.65, −0.23]
Cognitive flexibility			−0.46**	−0.50**	[−0.79, −0.20]
Sustained attention				0.15	[−0.18, −0.48]
R^2	0.14	0.16	0.19	0.19	
F	5.78***	5.77***	6.37***	5.86***	
ΔR^2		0.02	0.03	0.00	
ΔF^2		5.01*	10.05**	0.77	

Note. $N = 297$. CI = confidence interval. SSB = sugar-sweetened beverages. $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

mainly in older children. Thus, besides inhibitory control another executive functions domain seems to be associated to body weight and weight gain and, according to the present finding, this seems to be true in younger children, too.

On the other hand, the third cognitive domain, sustained attention, was not related to BMI percentiles in the current investigation. Previous findings concerning cognitive abilities other than executive functions are inconsistent. The literature review of Reinert et al. [18] reports six studies focusing on the association between obesity and general cognitive function with half of them demonstrating no relationship. Graziano et al. [22] considered sustained attention besides inhibitory control as part of cognitive self-regulation. Body weight of their preschool children, however, was only associated with the inhibitory performance but not with the attention performance. On the contrary, Cserjési et al. [24] showed the same result as for flexibility in their adolescent sample: a significant correlation of performance in the D2 sustained attention test with BMI and a significant group difference to the disadvantage of the obese. The existing inconsistencies in research literature might be due to the different age groups and to the use of different concepts and methods of the studied cognitive abilities. Hence, standardisation concerning the understanding and measurement of certain cognitions should be targeted and changes in outcomes according to stages of development should be taken into account when addressing this issue.

Besides the cognitive variables, parental body weight, BMI of mothers as well as BMI of fathers, was significantly associated with children's body weight. This finding is not surprising as it is consistent with the literature [11, 12, 14] and may be explained by genetic mechanisms as well as the shared environment. Family characteristics such as the knowledge of risk factors of overweight, eating habits, and food preferences but also physical activity patterns [46] may influence children's health behaviour and body weight. Migration background was revealed to be significantly associated with body weight as well. This finding is in line with previous national investigations [3, 11, 13]. The prevalence of overweight and obesity is found to be higher in children with migration background and the odds of overweight increased. Cultural attitudes and traditions concerning body weight and weight related behaviours (physical activity, TV consumption, and dietary habits), social integration (e.g., influencing recreational activities), and the knowledge of risk factors hampered by language barriers may explain this relationship.

Executive functions are seen to be crucial for self-regulatory behaviour [47]. They have already been related to health behaviour such as physical activity, snack food consumption, and fruit/vegetable intake in fourth graders [26]. Thus, the association with children's body weight may be mediated through more physical activity and healthy diet and less sedentary behaviour. As children just starting school are still more dependent on their parents and not completely autonomous in their planning and decision-making executive functions may, however, be crucial to appreciate and maintain new and healthy behaviour introduced by their caregivers, to control their thoughts, their behavioural impulses, and their feelings. Assuming this directionality, potential implications would be to integrate the promotion of executive functions in early obesity prevention efforts. Riggs et al. [48] suggested developing specific programme contents tailored to different obesity-risk profiles depending on certain behaviour patterns, weight consciousness (especially as children get older), and deficits in executive functions. Beyond the overweight and obesity issue, it has been shown that executive functions play an important role for success and health throughout the whole life. They are crucial for the social and emotional development, school readiness, and further academic and job success, as well as wealth and mental and physical health even in the long term [20, 21, 49, 50]. Regulating emotions in social conflicts, staying in control of oneself, adapting to rules when necessary, adopting effective problem-solving, and learning strategies are just a few examples when executive control is required. On the contrary, deficits are linked to social and health problems such as attention deficit hyperactivity disorder, obsessive compulsive disorder, depression, early school leaving early pregnancy, addiction, and criminality [20, 21]. Hence, strategies focusing on the improvement of these abilities would probably lead to positive effects in more than one health and life domain and even on a more public level (e.g., public safety and economic costs). In return, learning to cope with the different challenges in life successfully and to reduce emotional and social stress means reducing psychological risk factors for excessive weight gain again and starting a virtuous circle. There have already been national and international efforts aiming at an early improvement of executive functions in general [20, 50, 51]. These include school-based programmes and the integration of the promotion of these abilities in the official curriculum of primary schools in Germany. Thus, cognitive training in general and the integration of cognitive improvement in obesity interventions may be helpful ways to improve future generation's health and overall quality of life.

4.1. Strengths and Limitations. Results, however, should be interpreted in light of study limitations. First, the cross-sectional study design precludes any causal interpretation of the findings. Therefore, directionality of the association between cognitive functions and body weight still remains unclear: on the one hand, cognitive functions such as inhibitory control or cognitive flexibility may influence health behaviour and consequently weight development. On the other hand, body weight and variations in food intake, physical activity, and sedentary activities, for example, may also affect cognitive performance and brain development or the relationship may be bidirectional as well. Further studies are needed to clarify causality and underlying mechanisms in order to derive any implications.

Secondly, there are some limitations concerning missing data and selection bias in the present study. Due to the subsample and the missing or invalid data in the cognitive subtests and the parent questionnaire the number of subjects decreased from 1944 (in the Baden-Württemberg Study sample) to 297 in the final regression analysis. Missing data may have led to a form of selection bias. The cognitive subsample included, for example, more children with migration background. However, more children with migration background and with lower parental education level dropped out in the further data processing maybe partly due to comprehension difficulties. Furthermore, more children with higher BMI percentiles, higher consumption of sugar-sweetened beverages, and higher father's BMI were among those with missing data. Thus, children who entered the final analysis showed a more favourable profile in critical variables. Although migration background is still representative for school children in Germany, the final sample consisted of more children with higher parental education indicating a higher social status and lower body weight than usually found in the population (as reference, official statistics concerning German school children report 32.1% migration background, 23.9% tertiary parental education level, and 13.3% overweight or obesity [3, 52, 53]). On the contrary, the reduced sample size and statistical power may have led to an underestimation of significances. The inclusion of these missing cases could have potentially strengthened the final results. Furthermore, this may in part explain why no significant association between parental education and children's body weight was found.

Finally, underreporting in terms of recall bias or social desirability regarding children's lifestyle which was assessed via parental questionnaire should be taken into account and might explain the missing significant association of these variables with body weight. The objective standardised and direct measurements of cognitive and anthropometric data, on the other hand, as well as the large sample size constitute a strength of the study. Further, the focused age group is highly relevant as excessive weight gain is particularly pronounced at the age of school entry and important cognitive developments especially in executive functions relevant for a wide variety of behaviour and health outcomes take place.

5. Conclusions

In summary, cognitive abilities were significantly related to body weight of primary school children controlling for further weight influencing sociodemographic and lifestyle factors. This relationship concerns inhibitory control and cognitive flexibility, both processes considered as executive functions. As executive functions are crucial for self-regulation and disciplined behaviour including health behaviour, the finding indicates that promoting executive functions may assist in developing a healthy body weight and avoiding excessive weight gain in addition to already existing obesity prevention efforts. However, further research is necessary first, in particular longitudinal and intervention studies, to confirm the present findings, to determine the directionality of the association, and to investigate the impact of cognitive training on weight related outcomes.

Conflict of Interests

The authors declare that there is no conflict of interests.

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Research Article

Feasibility and Acceptability of an Early Childhood Obesity Prevention Intervention: Results from the Healthy Homes, Healthy Families Pilot Study

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Background. This study examined the feasibility and acceptability of a home-based early childhood obesity prevention intervention designed to empower low-income racially/ethnically diverse parents to modify their children's health behaviors. *Methods.* We used a prospective design with pre-/posttest evaluation of 50 parent-child pairs (children aged 2 to 5 years) to examine potential changes in dietary, physical activity, and sedentary behaviors among children at baseline and four-month follow-up. *Results.* 39 (78%) parent-child pairs completed evaluation data at 4-month follow-up. Vegetable intake among children significantly increased at follow-up (0.54 cups at 4 months compared to 0.28 cups at baseline, $P = 0.001$) and ounces of fruit juice decreased at follow-up (11.9 ounces at 4 months compared to 16.0 ounces at baseline, $P = 0.036$). Sedentary behaviors also improved. Children significantly decreased time spent watching TV on weekdays ($P < 0.01$) and also reduced weekend TV time. In addition, the number of homes with TV sets in the child's bedroom also decreased ($P < 0.0013$). *Conclusions.* The findings indicate that a home-based early childhood obesity prevention intervention is feasible, acceptable and demonstrates short-term effects on dietary and sedentary behaviors of low-income racially/ethnically diverse children.

1. Introduction

Childhood obesity remains a significant public health concern. While national health and nutrition examination survey (NHANES) reports suggest that obesity may have declined among children aged 2–5 years [1], these beneficial declines have not been evidenced across all geographic regions, racial/ethnic groups, or income levels [1, 2]. Recent data from the 2008–2011 Pediatric Nutrition Surveillance System found that while there were significant decreases in obesity prevalence among low-income preschoolers in 19 US states/territories, there were no significant changes in 21 US states/territories and there were significant increases in three US states/territories [2]. Further, research findings indicate that since 2008 there have been no appreciable changes in obesity trends among low-income preschoolers in the US state of Rhode Island, with obesity prevalence remaining above 16 percent [2]. Thus, Rhode Island remains one of the US states/territories with the highest obesity prevalence among low-income preschoolers for the 43 reporting US states/territories.

Additional findings from NHANES demonstrate that since 2003 there have been no changes in childhood obesity overall [1, 3]. In fact, one-third of children remain overweight or obese; 17% are obese [1] and severe obesity (≥ Class 2 adult obesity) is increasing with 8% of children meeting the criteria [3]. This is cause for concern because childhood obesity is associated with severe obesity in adulthood, early onset of obesity-related comorbidities such as metabolic syndrome, type 2 diabetes, cardiovascular diseases (CVD), certain cancers, negative impacts on mental health and quality of life, and increased economic and medical costs [2, 4, 5]. Recent estimates suggest that relative to a normal weight 10-year-old child the direct lifetime incremental medical cost for an obese 10-year-old is $12,660; in the aggregate, this will account for $9.4 billion in medical costs for this age group alone [4]. Taken together, the available evidence underscores the critical need to increase our efforts to reduce childhood obesity particularly in early life and prevent and/or delay concomitant onset of obesity-related comorbidities, the negative impacts on quality of life, and the economic consequences.

Childhood obesity is particularly prevalent among low-income children, as well as African American and Latino children [1, 6, 7], which suggests that it is essential to develop focused, appropriate, and targeted intervention strategies in these populations [7, 8]. The prevention and treatment of overweight in youth hinges on helping children and their families develop new lifestyles and create supportive environments in which healthful eating and physical activity (PA) can be promoted [9–11]. Family-based interventions are effective in the treatment of childhood obesity [12], but most of these interventions have been time intensive and costly and therefore not sustainable or scalable after research funding ends [13]. Moreover, most have focused mainly on nonminority, middle, or high income families and older children. Thus, there is a pressing need to develop and test early childhood obesity prevention and treatment approaches for low-income and minority families that are effective but also practical, acceptable, and sustainable [8, 9].

The Institute of Medicine strongly recommends that obesity prevention intervention begins in early childhood [14] and focus on prevention efforts among children from birth to five years. This is a critical age range because the mean age at which obesity begins is 5.5 years [15–17] and BMI at age 8 is predicted by BMI at age 2 [18]. Additionally, evidence suggests that children's eating and physical activity behavioral patterns are established in early life and are more difficult to change after the age of 5 [19–21]. Intervention research findings indicate that attempts to induce children to change their food preferences are more effective with younger than older children [8]. This suggests that interventions should target younger children to prevent obesity and to help achieve the US Task Force on Childhood Obesity goal of reducing childhood obesity prevalence to 5% by 2030 [22].

Modifying the home/family environment and parent behaviors are crucial intervention components for the prevention of early childhood obesity [23]. Family environments are vital for the development of food preferences, patterns of food intake, and eating styles that shape children's weight status [24]. Parents play an important role in shaping early eating patterns in children by controlling availability and accessibility of foods, meal structure, and food socialization practices. Parent related behaviors including food-related parenting style, modelling healthful eating behaviors, encouraging physical activity, and/or discouraging sedentary behaviors convey values and attitudes that promote children's health through reinforcing specific behaviors [12, 25]. Additionally, intensive involvement of parents in interventions to change overweight children's dietary and PA behaviors contributes to long term weight maintenance [12, 25]. When interventions change parental behavior toward children, children's behaviors change correspondingly, even if the child is not directly involved in the intervention [12]. In fact, greater weight loss and higher consumption of healthy foods are achieved with parent-focused interventions compared with interventions in which children are the main agents of change [12].

Although there has been considerable growth in the number of childhood obesity prevention interventions with parents of preschool age children in a variety of settings [26–29], more intervention efforts are needed. The results from these previous interventions demonstrate that parent-focused, childhood obesity prevention interventions are feasible and effective in creating some healthy behavior changes and outcomes among both parents and preschool age children [26–28, 30]. One such intervention, the fit women, infants and children (Fit WIC) pilot program, was implemented in five US states with low-income ethnically diverse parents [31, 32] and children who participated in the US federal program, special supplemental nutrition program for women, infants and children (WIC). Results from one of the Fit WIC pilot programs found that parents made significant changes in health behaviors and increased family fitness-related activities [32]. Further, research findings from another Fit WIC program found that parents increased self-efficacy to limit children's TV viewing, reduced actual TV time for both parents and children, and increased physical activity among children [33]. Other studies that focus on changing parent behaviors in the home setting also have found significantly less engagement in restrictive parental feeding practices among low-income Native American parents [27] and less aversion to mealtime among preschoolers, less weight gain, and lower BMIs among both children and parents [34]. Additional intervention studies also report increased availability of fruits and vegetables in the home and increased parent role modelling of fruit and vegetable intake with concomitant increases in children's intakes [35]. However, more childhood obesity prevention interventions are needed that (1) build upon promising results of these previous studies, [26, 30] (2) combine multiple health behaviors (i.e., physical activity, sedentary behavior, and dietary components), (3) engage low-income and ethnically diverse parents, (4) focus on the home environment, (5) include tailored intervention materials, (6) incorporate effective counseling methods, and (7) use less costly intervention methods that could be more easily replicated.

Thus, the purpose of this intervention, healthy homes, healthy families (HHHF), is to address existing gaps in the literature by conducting a pilot feasibility and acceptability study of a parent-driven, home-based intervention to modify health lifestyle behaviors among low-income racially/ethnically diverse children aged 2 to 5 years. The findings from HHHF will inform the design and implementation of a future randomized controlled trial.

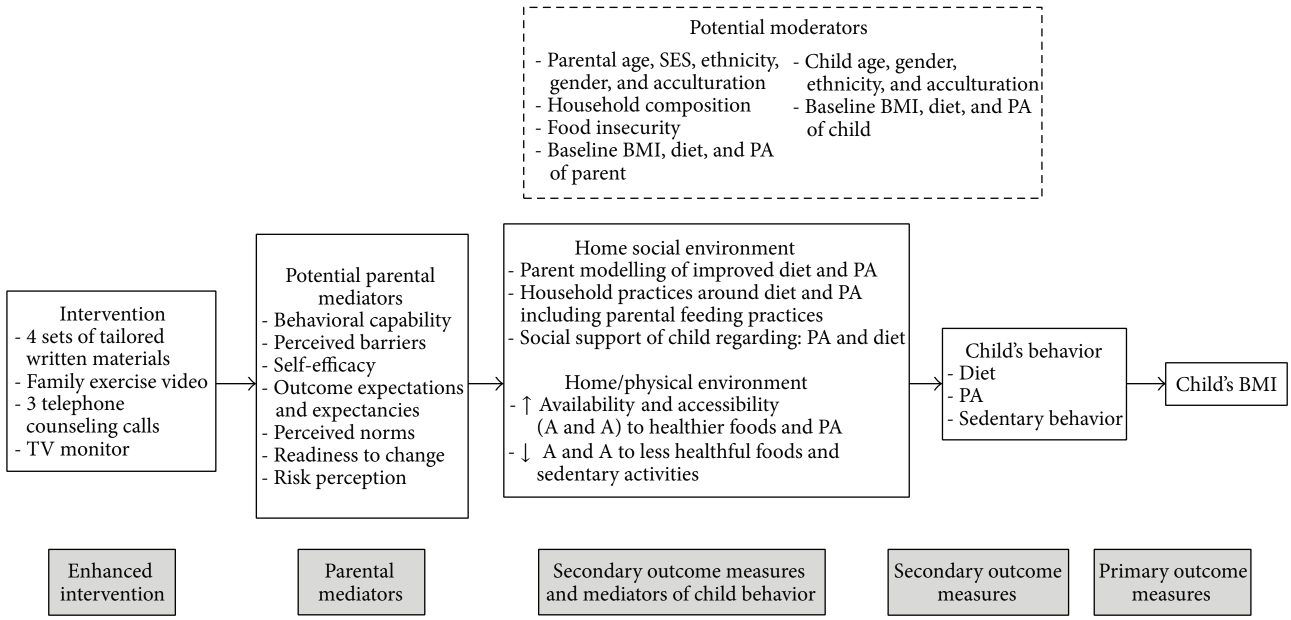

Figure 1: Healthy homes, healthy families intervention logic model.

2. Methods

2.1. Study Design. HHHF was an early childhood obesity intervention designed to encourage parents to improve healthy lifestyle behaviors related to eating and physical activity for themselves and their children. The study design was a prospective design with pretest/posttest measurement that combined telephone surveys and in-home visit measures collected at baseline and 4-month follow-up with 50 parent-child pairs. The study received approval from the Brown University Institutional Review Board. All participants received a financial incentive upon completion of each study visit.

2.2. Eligibility and Recruitment. The study recruitment occurred from 2009 to 2012, at twelve special supplemental nutrition program for women, infants and children (WIC) offices in low-income communities in Rhode Island. The research assistant approached WIC clients in the waiting room to tell them about the study and to ask if they would be interested in participating.

Interested participants were screened for eligibility. Study inclusion criteria required that participants were a parent or legal guardian of a child who was 2 to 5 years of age at the date of the baseline survey and had an age-sex specific body mass index (BMI) of 50th percentile or greater. The adult needed to be 18 years of age or older, live with the child at least 75 percent of the time, speak and read English, and be knowledgeable about the child's diet and physical activity behaviors. Eligible participants were asked to complete a baseline phone survey administered by trained interviewers using a computer automated telephone interface (CATI) system. Upon completion, research assistants were scheduled to visit the home at the convenience of the participant parent and child to complete an in-person survey, anthropometric measures, and a home audit. Verbal informed consent was received for the baseline telephone survey and then written informed consent (and verbal assent for children aged 4 and over) was received at the home visit. Upon completion of the home visit, parent-child pairs were considered enrolled. This process was repeated four months later as a follow-up assessment.

2.3. Intervention. HHHF included four sets of tailored written materials, three brief motivational interviewing (MI) telephone calls delivered by a trained lay counselor, a physical activity video tailored to the child's age, and a TV time monitoring device (TV Allowance by MINDMASTER, INC) to help parents monitor/restrict child's time spent on TV.

2.3.1. Theoretical Framework. The intervention was informed by social cognitive theory (SCT) [36–38], the conceptual model described by Golan and Weizman [39] and focus groups with the target audience and WIC nutrition counselors. The HHHF framework emphasized a familial approach to the prevention and treatment of overweight in young children with parents as the primary agent of change. As recommended by the Expert Panel of the Maternal and Child Health Bureau of Health Resources and Services Administration and Department of Health and Human Services, HHHF emphasized healthy lifestyle changes and no weight reduction [40]. HHHF focused on the formulation of new norms for healthy eating within the family through parents as role models and as sources of authority. HHHF also incorporated facilitating parental cognitive and behavioral change, increasing parenting skills and environmental change [39]. The HHHF intervention logic model is presented in Figure 1.

SCT is based on reciprocal determinism where a person's behavior, personal factors, and the environment interact constantly and where change in one domain affects changes in the other two domains [36–38]. Three major constructs of the SCT, self-regulation (personal regulation of goal-directed behavior), behavioral capability (knowledge and skills to perform specific tasks), and self-efficacy (confidence in one's ability to perform a particular behavior or overcome barriers to the behavior) were applied to HHHF intervention development. HHHF promoted self-regulation and outcome expectations through both the tailored intervention materials and the motivational interviewing (MI) components. Parents had the opportunity to choose topics for each mailing from a list of primary target behaviors that were an issue for their family. This provided opportunities for self-monitoring, decision making, and problem solving. The tailored written materials supported behavioral capability by providing the information needed for parents to modify the behaviors found to be associated with diet and PA in children and families. Parents' self-efficacy was developed by providing opportunities for them to choose to get materials to help them overcome specific barriers that they were experiencing. The MI calls offered social support and further developed self-efficacy through the exploration of desires, abilities, reasons, and needs for change [41, 42]. Counselors elicited positive outcome expectancies (benefits of change), encouraged problem solving if parents discussed barriers, and asked parents what steps they would take in the direction of change (goal setting).

2.3.2. Materials. After the baseline home assessment, study staff installed the TV monitor on the TV that the child used most often. Since the primary goal of the TV monitor was as an intervention tool to increase parents' self-efficacy for setting TV restrictions and limiting the child's time spent watching TV, we did not collect any data from this device. Approximately 1-2 weeks later, participants received their first package of tailored written intervention materials. The tailored written materials were mailed out in four stages over a 20-week period (approximately every 4 weeks), and the lay counselor MI calls occurred approximately 2 weeks after the mailing of each set of materials. A final set of tailored materials were mailed 1-2 weeks after the final counseling phone call. Materials were microtailored (tailored messages embedded into a page) or macrotailored (entire pages chosen or not). We accomplished the tailoring by using algorithms based on parents' answers to survey questions and home audit results as well as parent choice. We generated tailored feedback reports for each family on all target child behaviors, the home environment, and parent role modelling behaviors. We also personalized materials with the participant's and child's name.

The tailored printed materials focused on eight target behaviors found to be associated with obesity in children and families. These behaviors (increasing fruits and vegetables, reducing sugary drinks, limiting juice, low-fat instead of high fat milk, increasing physical activity, limiting fast food, removing TV from the child's bedroom, and limiting screen time) were all within control of the parent. If the family was not meeting the guideline for a target behavior, the computer populated a list of choices. We then presented the list to parents as areas where change was possible. Parents then chose a topic for each mailing from this list of primary target behaviors that were an issue for their family. We conducted a similar process for barriers that parents identified as problem areas such as the cost of healthy eating, cost of physical activity, children upset about changing foods or household rules, picky eaters, time for healthy eating, time for PA, children's choices/habits, lack of knowledge/skill, and lack of social support. Parents could receive up to a total of five barriers pages. In addition, parents could choose up to four tailored recipe pages.

2.3.3. Motivational Interviewing-Based Telephone Intervention. In between each of the four tailored mailings, parents received a brief motivational interviewing (MI) call designed to support their efforts to make changes to the social and physical home environment [41, 42]. The MI calls were designed to be 10–20 minutes long and to be delivered three times over the course of the intervention. These calls were digitally recorded.

We recruited four women to serve as lay MI counselors for the enrolled parents/guardians (one dropped out early due to the time commitment). We selected counselors who resided in Rhode Island and who had some experience with behavior change interventions but not specifically with MI. One counselor was Hispanic and three were non-Hispanic white and all had experience working with low-income populations. A facilitator, Dr. Drenner, trained through the motivational interviewing network of trainers (MINT), trained the lay counselors over seven evenings for a total of 12 hours. The MI training focused on the primary principles and techniques of the overall MI style and also on how these elements related to the specific behavior change targets of HHHF.

Once the telephone counseling began, Dr. Drenner monitored a random sample of the recorded telephone counseling sessions and continued coaching the counselors in group meetings and in individual sessions. She held group coaching meetings approximately biweekly both in-person and via conference call. Additionally, she held individual coaching sessions via telephone that focused on feedback on one or more of the digitally recorded telephone calls. Coaching was an opportunity for counselors to get consultation on both the content of the calls and specific behaviors related to MI. Dr. Drenner coded random counselor telephone calls using elements of the Motivational Interviewing Treatment Integrity Scale on global scores of empathy, behavior counts of reflections, and open and closed questions [41, 43].

Intervention adherence assessment included counselor's focus on (1) a specific target behavior, (2) assessment of importance and confidence of the chosen behavior, (4) goal setting, and (5) on calls 2 and 3, checking with the parent to see if they had met the set goal. Counselors elicited parents' own desire, ability, reason, and need for change and self-efficacy for change through reflection and affirmation of parents' effort to create a healthy environment for their child and family. Each participant received a tailored MI feedback page in the subsequent mailing summarizing the importance and confidence regarding the topic they discussed as well as the next step that the participant said they would take. If the counselor was unable to complete the call (after 3 phone call attempts), the participant received an MI feedback page informing them of the missed call as well as when they would receive the next call and a set of tailored materials based on the last contact.

2.3.4. Measures

Anthropometrics. Children's and parent's/guardian's heights and weights were measured at baseline and follow-up. To obtain height measurements, children were measured without shoes using a portable stadiometer (Seca 213). Height was measured to the nearest 0.1 cm and averaged across 2 measurements. To obtain weight measurements, children wore light clothing and were weighed without shoes to the nearest 0.1 kg using a digital scale (Tanita BWB-800S Digital Scale). The average of 2 weight measurements was taken. BMI was calculated using the formula kg/m^2, from which the BMI for age-sex specific percentiles was calculated using the centers for disease control and prevention (CDC) 2000 growth charts.

Dietary Habits. At the time of study implementation, there was not a well validated dietary assessment tool for preschoolers that comprehensively assessed children's intake of the foods and beverages we were trying to change; so we modified questions on existing validated tools to be appropriate for asking parents about their child's intake. To assess the child's fruit, vegetable, sugar sweetened beverage, and soda intakes, we adapted items from the validated National Cancer Institute (NCI) fruit and vegetable all-day screener which measures participants' usual consumption over the past month. The all-day screener was validated by conducting cognitive interviews with adults and examining correlations of the measure with four nonconsecutive 24-hour dietary recalls ($r = 0.50$) [44]. To determine frequency of food/beverage intake, the original survey asked the following: "over the last month, how often did you drink/eat [item]?" There were 10 response options ranging from never to 5 or more times per day. To assess portion size, the survey asked the following: "each time you drank/ate [item], how much did you usually drink/eat?" Response options corresponded to the frequency and portion size of the respective food/beverage. For the HHHF study, we substituted each statement with "Your Child" instead of "You" so that we could assess children's intakes [44]. We also modified these portion size choices to be appropriate for amounts that a preschooler would consume using the MY Plate recommendations for young children [45, 46].

We also obtained questions used in the Fit WIC [32] study to assess parent reports of their children's water, milk, and 100 percent fruit juice intakes and children's frequency of eating at fast food restaurants [32]. These items were not validated but were modified from existing child-based questionnaires to be appropriate for preschool age children [32]. These questions have also been recommended for inclusion in national surveillance data collection by the New South Wales Centre for Public Health Nutrition in Australia [47].

Physical Activity. We assessed children's outdoor playing time using a validated measure developed by Burdette and colleagues for preschool children's activity [48]. The correlation of the outdoor play measure with accelerometer data was $r = 0.20$ [48]. Parents reported the time (in minutes) that children engaged in weekday outdoor activity and weekend outdoor activity.

Sedentary Behaviors. Parents reported children's TV use including the number of hours of TV/video/DVD/playing the child "usually watches" on weekdays and weekend days [49]. We also asked parents to report whether the child watches TV during meals and snacks. These questions have demonstrated high test-retest reliability ($r = 0.94$) with older children [50] and have been used successfully in studies with children 1–5 years of age [49–51].

Parent Behaviors. We assessed parent behaviors related to role modelling, the home food environment, family support for PA, family encouragement for PA/diet, and parent household rules related to PA/diet. To examine parent role modelling, we adapted items from the Home Environment Survey developed by Gattshall et al. [52]. We modified these items to align with HHHF outcomes based on results from in-depth cognitive interviews with HHHF parents. Example items include "on how many days last week did your child see you walk to get from place-to-place instead of drive?" and "on how many days last week, did your child see you eating fast food?" To examine the home food environment, we developed items specific to HHHF intervention outcomes including the number of times per day the parent provided the child with fruits and vegetables, the number of days per week the child consumed low-fat milk, and the number of days per week that healthy/unhealthy foods were available (See Table 3).

We examined parental support for child physical activity using three items from the Aventuras Para Niños study to inquire about parents/family activity together and transportation [53]. Response options ranged from 1 to 7 days per week. We also included a separate item about family support for the child to play outside that was developed specifically for this study. We also adapted items from the Aventuras Para Niños study [54] that examined whether parents provided praise/encouragement for children's diet and physical activity behaviors; we also created additional questions that were adapted to HHHF outcomes. Example questions included "on how many days this past week did you praise your child for eating fruits and vegetables" and "on how many days this week did you praise your child for being physically active." We also examined parents' household rules related to diet/PA using items adapted from the Aventuras Para Niños Study and items developed specifically to the HHHF intervention outcomes [53, 54]. Based on pretest results from the cognitive interviews with HHHF participants, we modified the items and response options from the Aventuras Para Niños Study. Sample items include "how often do you limit the amount of time your child spends watching TV or videos" and "how often do you limit the amount of 100% fruit juice your child drinks." Response options ranged from 1 = never to 5 = always.

Demographics. Parents self-reported parent and child gender, race, ethnicity, and age. Parents also self-reported marital status and socioeconomic status-related variables including employment, education, and total annual household income. Additional parent-reported demographics included household composition and food insecurity (i.e., how often the parent worried about having enough food in the home).

2.4. Data Analysis. Demographic variables were collected for parent, as well as the child, and categorized as follows: gender (male versus female), race (White, Black, Asian, Native Hawaiian or other Pacific Island, American Indian or Alaska Native, mixed race, other), and ethnicity (Hispanic versus non-Hispanic). Mean age and BMI were determined and treated as continuous variables. Descriptive statistics were computed with frequencies and proportions for categorical variables and means for continuous variables. Chi square tests were used to compare categorical psychosocial data and categorical demographic variables. General linear models were constructed to compare mean differences of dietary intake, physical activity, sedentary behaviors, child BMI, and parent behaviors pre-/posttest. Significance criterion was set at $\alpha < 0.05$. All analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC).

3. Results

Figure 2 presents the study recruitment flow diagram. Of the 143 potential child-parent pairs initially recruited by the research assistant, 7 were ineligible to complete additional screening. A total of 136 parent-child pairs were eligible to complete the phone survey; 59 completed the survey, 18 declined to participate, 43 were unable to be contacted, and 16 were ineligible to continue the screening process. Fifty-nine eligible parent-child pairs scheduled the in-person survey and home audit. At this stage, 4 declined to participate and 5 were unable to be contacted leaving a total of 50 parent-child pairs who enrolled in the intervention. At four-month follow-up, 39 parent-child pairs (78%) completed both the telephone and the home audit components of the evaluation, 2 declined to participate, and 9 were unable to be contacted.

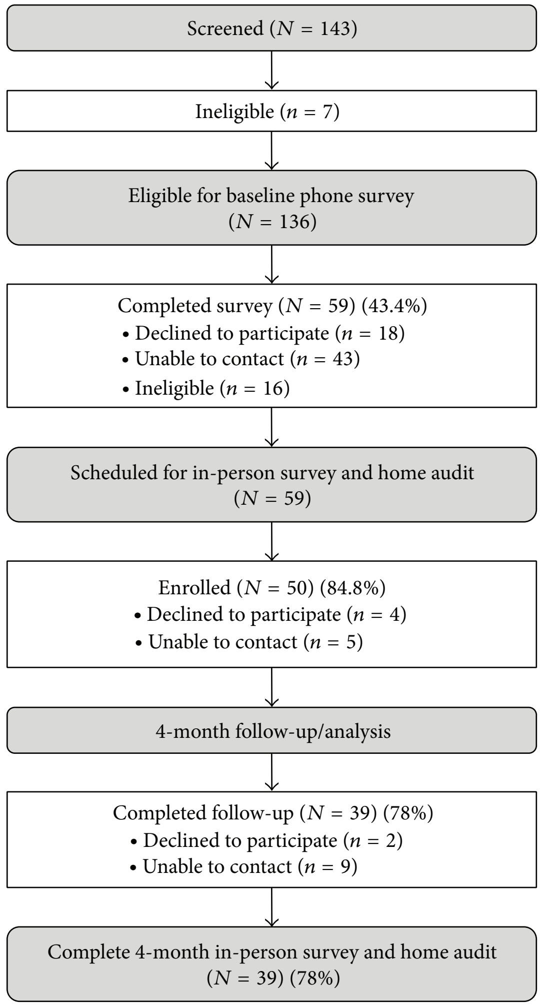

Figure 2: Healthy homes, healthy families intervention recruitment flow diagram.

Baseline demographic and BMI characteristics of the participating children and parents/guardians are presented in Table 1. Children enrolled averaged 3 years, 7 months of age, with parents/guardians averaging 31 years. All of the adult participants were parents and 98% of them were women. Forty percent of the parents described themselves as Hispanic, with 50% of the enrolled children being described as Hispanic. Almost half (48%) of the parents were White, 14% Black, and 4% mixed race and 38% of children were White, 14% Black, and 14% mixed race. Just over half (54%) of the parents were single, 36% were married, and the remaining 10% reported that they were separated or divorced. About one-quarter each of the participating parents were employed full time, part time, or unemployed, with an additional 12% homemakers, 10% students, and 4% disabled. The educational level attained for participating parents/guardians reached high school or general educational development (GED) credential for the highest proportion (46%) and some college or an associate's degree for 32%. The remaining group included those with less than high school education (8%), technical or vocational school (6%), and either a bachelors (6%) or postgraduate degree (2%). Just over one-third of the families had no other children in the home, but roughly a quarter each reported one or two children and 16% reported 3 or more other children in the home. Also, over one-third of parents/guardians were the sole adult at home, with 42% reporting two adults and 10% reporting three or more. Slightly more than one-fourth of parents/guardians reported food insecurity (concern over having enough food). Household income was generally low: 14% of parent-child pairs resided in households with <\$6,000 per year and 20% in \$6–\$11,999 per year. Only 4% of parent-child pairs resided in households where the total annual income was between \$24–\$29,999 and 14% in the \$36,000 or higher income group.

The average BMI of the children enrolled in HHHF was at the 65th percentile for age and sex. The recruited children were mostly within the range of 50th–85th percentile (72%), with an additional 14% each in the overweight (≥85th, <95th %ile) and obese (≥95th %ile) categories. The parents/guardians averaged a BMI of 29 kg/m^2. The highest proportion of adult participants were obese (48% with

Table 1: Demographic characteristics of the 50 parent-child pairs in healthy homes, healthy families.

Variable	Mean ± SD or n (%)
Parent gender (female)	49 (98)
Relationship to child	
Mother	49 (98)
Father	1 (2)
Percent Hispanic or Latino? (parent)	20 (40)
Percent Hispanic or Latino? (child)	25 (50)
Race (parent)	24 (48)
White	7 (14)
Black	1 (2)
Asian	1 (2)
Native Hawaiian or other Pacific Island	3 (6)
American Indian or Alaska Native	4 (2)
Mixed race	12 (24)
Other	24 (48)
Race (child)	
White	19 (38)
Black	7 (14)
Asian	1 (2)
Native Hawaiian or other Pacific Island	1 (2)
American Indian or Alaska Native	3 (6)
Mixed race	7 (14)
Other	12 (24)
Marital status	
Single	27 (54)
Married	18 (36)
Divorced	1 (2)
Separated	4 (8)
Employment status	
Employed full time	12 (24)
Employed part time	13 (26)
Unemployed	12 (24)
Disabled	2 (4)
Student	5 (10)
Homemaker	6 (12)
Education	
Less than high school	4 (8)
High school or general educational development credential (GED)	26 (46)
Vocational or technical school or Some college or associate degree	19 (38)
Bachelor's degree	3 (6)
Postgraduate degree	1 (2)
Number of other children living in household	
0	17 (34)
1	13 (26)
2	12 (24)
3	5 (10)
4	2 (4)
5	1 (2)
Number of adults (including yourself) living in household	
1	18 (36)
2	21 (42)
3	6 (12)
4	3 (6)
5	1 (2)
6	1 (2)
Worried about not having enough food (yes)	14 (28)
Annual household income	
<\$6,000	7 (14)
\$6,000 to \$11,999	10 (20)
\$12,000 to \$17,999	4 (8)
\$18,000 to \$23,999	10 (20)
\$24,000 to \$29,999	5 (10)
\$30,000 to \$35,999	2 (4)
\$36,000	7 (14)
Don't know or refused	5 (10)
BMI category (parent)	
Underweight	4 (2)
Healthy weight	14 (28)
Overweight	10 (20)
Obese	24 (48)
BMI category (child)	
Underweight (<5th percentile)	0
Within range (5th to <85th percentile)	36 (72)
Overweight (85th to <95th percentile)	7 (14)
Obese (≥95th percentile)	7 (14)
Mean Age	
Parent or guardian	28.38 ± 6.18
Child (age in months)	43.12 ± 11.88
Mean BMI	
Parent or guardian	29.81 ± 8.21
Mean BMI %ile for age and sex	
Child	65.36 ± 27.48

BMI ≥ 30), 20% were overweight (BMI ≥ 25, <30), 28% were normal weight, and 4% were underweight.

3.1. Process Evaluation. Process evaluation measures are presented in Table 2. According to parent reports on the follow-up survey, over 72% of parents received three MI calls, 19% received two calls, 2.7% received no calls, and 5.5% reported other. However, according to process evaluation data from

Table 2: Process evaluation data.

Variable	n (%)	n (%)	n (%)	n (%)	n (%)
Health coach overall					
	None	One	Two	Three	Other
How many phone calls did you receive from the health coach (reported by participants)	0 (0)	1 (2.78)	7 (19.44)	26 (72.22)	2 (5.56)
Actual calls completed according to counselors	4 (8)	13 (26)	25 (50)	8 (16)	
	Not at all	A little bit	Some	A lot	
How much did the health coach make you think about your child's health	1 (2.56)	2 (5.13)	9 (23.08)	27 (69.23)	
How much did you feel understood by the health coach	0 (0)	1 (2.56)	9 (23.08)	29 (74.36)	
	Agree a lot	Agree a little	Neither agree nor disagree	Disagree a little	Disagree a lot
The health coach					
Made it comfortable for me to talk about my child's health	34 (87.18)	1 (2.56)	4 (10.26)	0 (0)	0 (0)
Respected me	36 (92.31)	0 (0)	3 (7.69)	0 (0)	0 (0)
Helped me to think about why health changes might be important to my child	30 (76.92)	4 (10.26)	3 (7.69)	1 (2.56)	1 (2.56)
Expressed caring and understanding when talking with me about my child's health	35 (89.74)	1 (2.56)	2 (5.13)	0 (0)	1 (2.56)
Addressed my concerns about my child's health	33 (84.62)	2 (5.13)	2 (5.13)	1 (2.56)	1 (2.56)
Helped me to set a goal for positive changes in my child's health	28 (71.79)	7 (17.95)	3 (7.69)	1 (2.56)	0 (0)
I felt pressured by the health coach to make changes in my child's health	2 (5.13)	0 (0)	3 (7.69)	2 (5.13)	32 (82.05)
The HHHF materials					
Were written specifically for you	26 (68.42)	4 (10.53)	5 (13.16)	3 (7.89)	0 (0)
Had information you could use	31 (81.58)	4 (10.53)	1 (2.63)	1 (2.63)	1 (2.63)
Had information you could believe	27 (71.05)	8 (21.05)	3 (7.89)	0 (0)	0 (0)
Were easy to read	36 (94.74)	2 (5.26)	0 (0)	0 (0)	0 (0)
The TV monitor					
Was easy to use	17 (73.91)	2 (8.70)	0 (0)	1 (4.35)	3 (13.04)
Was useful	10 (43.48)	4 (17.39)	2 (8.70)	2 (8.70)	5 (21.74)
Is a great tool for parents because it is a "set it and forget it" device for them	13 (56.52)	4 (17.39)	3 (13.04)	1 (4.35)	2 (8.70)
Helped your child spend more time doing physically active things	11 (47.83)	2 (8.70)	4 (17.39)	2 (8.70)	4 (17.39)

the counselors, fewer calls were completed; 16% of parents received three calls, 50% received two calls, 26% received one call, and 8% received no calls.

Parents/guardians reported that the health coach made them "think about their child's health a lot" (69%) and "felt understood by the health coach a lot" (74%). A very high proportion of parents/guardians agreed a lot that "they felt respected" (92%), that "the health coach expressed caring and understanding when discussing their child's health" (89%), and that "the health coach made it comfortable for [the parent] to talk about their child's health" (87%). Also, the parents/guardians agreed a lot that "the health coach addressed concerns about the child's health" (84%), "helped [the parent] to think about why health changes might be important to the child" (77%), and "helped [the parent] to set goals for positive change in the child's life" (71%).

Most parents reported receiving three (45%) or four (42%) mailings, and the majority read all or most of them (82%). Most parents found the materials somewhat (34%) or very (55%) interesting and 95% reported that "they were very clearly written." Parents agreed a lot that "the materials were easy to read" (95%), "had information they could use," (82%) or believe (71%), and "were written especially for [the parent]" (68%). At the time of the four-month follow-up,

Table 3: Changes in child outcomes from baseline to month 4 and change scores for healthy homes, healthy families participants.

Variable	BL intervention group mean ± Std. Dev (95% CI) (*n*)	M4 intervention group mean ± Std. Dev (95% CI) (*n*)	Change (BL to M4) intervention group mean ± Std. Dev (95% CI) (*n*)	*P* value
BMI				
Child BMI for age	65.36 ± 27.48 (57.55–73.17) (50)	63.82 ± 29.73 (54.19–73.46) (39)	−1.77 ± 10.93 (−5.31–1.78) (39)	0.319
Food habits				
Servings of vegetables/day	0.28 ± 0.34 (0.19–0.38) (50)	0.54 ± 0.64 (0.33–0.75) (39)	0.28 ± 0.53 (0.11–0.45) (39)	0.001*
Servings of fruit/day	0.96 ± 1.13 (0.64–1.28) (50)	1.17 ± 1.17 (0.78–1.56) (37)	0.21 ± 1.04 (−0.13–0.56) (37)	0.222
Ounces of 100% fruit juice/day	16.01 ± 15.10 (11.72–20.30) (50)	11.94 ± 11.14 (8.33–15.55) (39)	−3.92 ± 11.27 (−7.57–−0.27) (39)	0.036*
Ounces of sweetened drinks and soda/day	8.80 ± 18.52 (3.48–14.12) (49)	5.06 ± 12.77 (0.86–9.25) (38)	−4.23 ± 19.65 (−10.78–2.32) (37)	0.198
Oz/day child drinks water	13.98 ± 13.47 (10.77–17.85) (49)	13.42 ± 8.52 (10.62–16.22) (38)	0.61 ± 9.31 (−2.46–3.67) (38)	0.691
Oz/day child drinks milk	15.40 ± 9.78 (12.62–18.18) (50)	13.44 ± 6.88 (11.21–15.67) (39)	−0.46 ± 8.20 (−3.12–2.20) (39)	0.727
Times/week child eats fast food	1.16 ± 1.23 (0.81–1.51) (50)	0.86 ± 0.83 (0.59–1.13) (39)	−0.29 ± 1.06 (−0.64–0.05) (39)	0.091
Physical activity habits (min)				
Weekday child exercises	194.98 ± 171.56 (145.70–244.26) (49)	164.21 ± 170.42 (108.20–220.23) (38)	−13.35 ± 138.86 (−59.65–32.95) (37)	0.562
Weekend day child exercises	206.02 ± 185.71 (152.68–259.36) (49)	182.90 ± 169.28 (128.02–237.77) (39)	5.74 ± 132.50 (−37.82–49.29) (38)	0.791
Weekday child spends playing outside	96.80 ± 107.49 (66.25–127.35) (50)	59.51 ± 58.14 (40.66–78.36) (39)	−22.28 ± 59.33 (−41.52–−3.05) (39)	0.024*
Weekend day child spends playing outside	136.40 ± 126.76 (100.37–172.43) (50)	70.67 ± 73.91 (46.71–94.62) (39)	−41.13 ± 91.99 (−70.95–−11.31) (39)	0.008*
Sedentary behavior (min)				
Weekday child spends watching TV	146.90 ± 98.71 (118.85–174.95) (50)	110.77 ± 81.19 (84.45–137.09) (39)	−49.87 ± 99.88 (−82.25–−17.49) (39)	0.003*
Weekend day child spends watching TV	149.00 ± 96.27 (121.64–176.36) (50)	133.72 ± 91.16 (104.17–163.27) (39)	−20.38 ± 119.80 (−59.22–18.45) (39)	0.294

*Indicates significant group differences, $P < 0.05$.

87% were still using the written materials and 71% had shared the materials with others.

The TV monitor received somewhat mixed results. The monitor was used always or often (33%), sometimes (13%), but also rarely or never (35%), or the parents/guardians chose not to have a TV monitor (18%). Most parents/guardians (74%) agreed a lot that "the device was easy to use." However, only about half of participating parents/guardians agreed a lot that "the monitor was useful" (43%) and "was a great tool because they could set it and forget it" (57%) and that "the device helped the child spend more time doing physically active things" (48%). Most parents disagreed a lot (52%) or a little (9%) that "the child would get upset when the TV monitor was turned on."

3.2. Intervention Outcome Evaluation. Baseline and change in child outcome measures are presented in Table 3. At baseline, parents reported that children consumed 0.28 cups of vegetables and 0.96 cups of fruit each day. Also, children consumed a mean of 16 ounces of 100% fruit juice and 8.8 ounces of sweetened drinks per day. Children also averaged 14 ounces of water and 15 ounces of milk consumption per day. Parents also reported children eating fast food just over one time per week. Parents reported that children engaged in physical activity and averaged 195 minutes on week days and 206 minutes on weekends. Also, children averaged 97 minutes on week days and 136 minutes on weekends of outside play. Conversely, children also engaged in sedentary behaviors and averaged 147 minutes on week days and 149 minutes on weekend days watching TV.

Although mean BMI percentile did decrease (−1.77 kg/m^2) from baseline to month 4, this change was not significant. However, significant change was found in children's daily vegetable intake. Higher intake was reported at month 4 of follow-up (0.54 cups) compared with baseline (0.28 cups, $P = 0.001$). In addition, significant reductions were observed in mean ounces of fruit juice consumed each day (11.94 ounces at 4 months compared to 16.01 ounces at baseline, $P = 0.036$).

While there were no significant changes in intakes for other beverages, all changes were in the direction expected with 4-ounce reductions in sweetened beverage intakes per day and a 0.6-ounce increase in water intake per day. Also, the reduction in the number of times in which children consume fast food each week approached statistical significance ($P = 0.09$). Physical activity and sedentary behaviors also changed over the course of the intervention. From baseline to 4 months, reported minutes of time spent playing outside significantly decreased (97 minutes on weekdays and 136 minutes on weekend days at baseline compared to 60 minutes on weekdays and 71 minutes on weekend days at 4 months $P = 0.0243$ weekday; $P = 0.0082$ weekend). However, parents/guardians reported that children spent less time watching TV on weekdays (111 minutes compared with 147 minutes per day at baseline, $P < 0.01$); weekend TV time also decreased by 20 minutes, but this change was not statistically different. We also observed that the percent of households with TVs present in the child's bedroom significantly decreased from 70% to 60%, $P < 0.0013$ from baseline to follow-up (data not shown in table).

Baseline and 4-month change in parent behaviors related to parent role modelling, the home food environment, family support for PA, family encouragement for PA/diet, and parent household rules are presented in Table 4. Parent role modelling: parents reported significant increases in the days that their child saw them drink low-fat milk (0.87 days, $P = 0.0324$) and there was a borderline significant decrease in the number of days that their child saw them eating fast food (−0.33 days, $P = 0.0513$). Parents reported statistically significant increases in the number of days that their child saw them walking from place-to-place (0.71, $P = 0.0292$) and exercising (0.72, $P = 0.0094$). Parents also reported a statistically significant decrease in the average minutes per day that their child saw them watching TV (−47.18 min, $P = 0.0158$). The home food environment: parents reported an increase in the number of times that they gave their child 1% or skim milk (1.13 times, $P = 0.0350$). Family support for PA: there were no significant changes in family support for PA from baseline to four-month follow-up. Family encouragement for PA/diet: parents at follow-up were more likely to praise their child for drinking low-fat milk (2.2 days compared with 0.9 days per week, $P = 0.0181$) and for eating fruits and vegetables (4.5 days compared with 2.6 days per week, $P < 0.0001$). Also, parents were more likely after the intervention to encourage their child to watch less TV (4.3 days compared to 2.4 days per week, $P = 0.0105$). Parent household rules: most parents at follow-up were more likely to limit the number of days that their child spent playing video games (3.51 days compared to 3.22 days, $P = 0.0271$). Also, parents were more likely to limit the number of days that their child drank 100% juice (3.15 days compared to 2.5 days, $P = 0.0017$) and limit the number of days that their child ate fast food (4.44 days compared to 3.82 days, $P = 0.0099$).

4. Discussion

The main objective of this study was to examine the feasibility of a home-based early childhood obesity intervention to modify parent and child health behaviors. This pilot intervention showed great promise in demonstrating that a home-based intervention could be successful in changing some parental behaviors as well as dietary and sedentary behaviors of children. Many changes were either statistically significant or in the posited direction, which is impressive given that the sample size was only 50 parent-child pairs and the intervention was monthly for only four months in duration. Overall, participating parents/guardians reported positively on the components of the intervention. The telephone counselors were well received and the tailored written materials were well used. While there were some discrepancies in parent reports of receipt of MI counseling calls, we think this could be due to the parents confusing the counseling calls with the baseline and follow-up evaluation calls or confusing attempts to reach them with actual MI calls. However, the response to the TV monitor was somewhat mixed; though some parents/guardians seemed to fully use the device others did not report using it at all. The overall pilot feasibility, intervention findings, and parent reported acceptability demonstrate significant potential for HHHF to be implemented as a future randomized controlled trial for the prevention of childhood obesity. Additionally, we had good participant retention at four-month follow-up.

The current study also found significant improvements in children's daily servings of vegetables and reductions in 100% juice intake, but no statistically significant changes in sweetened beverage, water, milk intake, or fast food consumption were evidenced. On average, children's total servings of vegetables almost doubled over the course of the intervention. However, these intake levels are still lower than recommendations for children of this age (1 to 1.5 cups each of fruits and vegetables per day) [45]. Many of the other dietary changes, especially reductions in sweetened beverage and fast food intake, might have been statistically significant with a larger sample size. Research findings from other early childhood interventions and systematic review studies also found that increases in fruit and/or vegetable intake were key behavioral changes made but that there were no changes made in sweetened beverage intake or fast food consumption [30, 35, 55, 56]. In contrast, results from the ROMP & Chomp community-wide intervention with young children in Geelong, Australia, found both significant reductions in nutrient-poor energy dense foods and sugar sweetened beverage intakes and also increased fruit, vegetable, and water intakes [21].

It is important to note that more than one-fourth of HHHF participating parents identified food insecurity as a key concern, which may have affected intervention efficacy. The finding of high levels of parent reported food insecurity is similar to reports from other interventions with low-income parents of young children [9]. The HHHF intervention did include practical strategies for low-resource households such as choosing produce that is in season and healthy options for frozen or canned products. However, future interventions

Table 4: Changes in parent behaviors from baseline to month 4 and change scores for healthy homes, healthy families participants.

Variable	BL Mean ± Std. Dev (*n*) (95% CI)	M4 Mean ± Std. Dev (*n*) (95% CI)	Change BL to M4 Mean ± Std. Dev (*n*) (95% CI)	*P* value (2 sided)
Parent role modelling of food practices				
Times/day child saw you eat fruit or vegetables w/meal	2.44 ± 2.03 (50) (1.86–3.02)	2.42 ± 2.05 (38) (1.75–3.09)	0.11 ± 3.22 (38) (−0.95–1.16)	0.8414
Times/day child saw you eat fruit or vegetables as a snack	1.90 ± 2.01 (50) (1.33–2.47)	1.77 ± 1.51 (39) (1.28–2.26)	−0.03 ± 2.42 (39) (−0.81–0.76)	0.9476
Days child saw you drink low-fat milk	1.74 ± 2.62 (50) (1.00–2.48)	2.41 ± 2.90 (39) (1.47–3.35)	0.87 ± 2.45 (39) (0.08–1.67)	0.0324*
Days child saw you eating fast food	1.30 ± 1.37 (50) (0.91–1.69)	0.90 ± 1.33 (39) (0.47–1.33)	−0.33 ± 1.03 (39) (−0.67–0)	0.0513
Times/day child saw you drink sweetened drinks	1.84 ± 1.60 (50) (1.39–2.29)	1.49 ± 1.32 (39) (1.06–1.91)	−0.15 ± 1.91 (39) (−0.77–0.47)	0.6184
Parent role modelling of activity practices				
Days child saw you walk from place to place	1.41 ± 2.21 (49) (0.77–2.04)	1.77 ± 2.38 (39) (1.00–2.54)	0.71 ± 1.93 (38) (0.08–1.34)	0.0292*
Days child saw you exercising	0.73 ± 1.45 (49) (0.32–1.15)	1.54 ± 2.16 (39) (0.84–2.24)	0.72 ± 1.64 (39) (0.19–1.25)	0.0094*
Min/day child saw you watching TV	131.90 ± 100.58 (50) (103.31–160.49)	88.08 ± 58.62 (39) (69.07–107.08)	−47.18 ± 116.61 (39) (−84.98–−9.38)	0.0158*
Min/day child saw you playing on computer	73.60 ± 109.44 (50) (42.50–104.70)	50.38 ± 77.75 (39) (25.18–75.59)	−17.05 ± 68.86 (39) (−39.37–5.27)	0.1303
Parental support for child's physical activity				
Days you did physically active things w/your child	2.20 ± 2.15 (50) (1.59–2.81)	2.46 ± 2.17 (39) (1.76–3.17)	0.28 ± 2.65 (39) (−0.58–1.14)	0.5095
Days you did physically active things as a family	1.80 ± 1.82 (50) (1.28–2.32)	1.33 ± 1.80 (39) (0.75–1.92)	−0.41 ± 2.05 (39) (−1.07–0.25)	0.2187
Days/week you took child to be physically active	3.40 ± 2.09 (50) (2.81–3.99)	2.97 ± 2.24 (39) (2.25–3.70)	−0.38 ± 3.01 (39) (−1.36–0.59)	0.4305
Days/week you suggested child to play outside	3.46 ± 2.62 (50) (2.72–4.20)	2.44 ± 2.01 (39) (1.78–3.09)	−0.79 ± 3.06 (39) (−1.79–0.20)	0.1133
Home food environment				
Times/day you gave child fruit to eat	1.86 ± 1.22 (49) (1.51–2.21)	2.21 ± 1.49 (39) (1.72–2.69)	0.47 ± 1.62 (38) (−0.06–1.01)	0.0802
Times/day you gave child vegetables to eat	1.78 ± 1.52 (50) (1.35–2.21)	1.64 ± 1.22 (39) (1.24–2.04)	−0.05 ± 1.69 (39) (−0.60–0.49)	0.8503
Days/week you have cut up fv for child to eat	3.88 ± 2.60 (50) (3.14–4.62)	3.81 ± 2.22 (32) (3.01–4.61)	0.22 ± 2.71 (32) (−0.76–1.20)	0.6510
Days per week the child consumed low-fat milk	3.84 ± 3.21 (50) (2.93–4.75)	4.64 ± 3.14 (39) (3.62–5.66)	1.13 ± 3.22 (39) (0.08–2.17)	0.0350*
Days/week had soda in your home for child to drink	0.82 ± 1.84 (50) (0.30–1.34)	0.90 ± 1.70 (39) (0.35–1.45)	−0.05 ± 2.03 (39) (−0.71–0.61)	0.8752
Days/week you had sweetened drinks in your home for child to drink	2.90 ± 2.87 (50) (2.08–3.72)	2.85 ± 2.87 (39) (1.92–3.78)	−0.31 ± 3.13 (39) (−1.32–0.71)	0.5429
Days/week you had sweets for child to eat	3.94 ± 2.67 (50) (3.18–4.70)	3.74 ± 2.59 (39) (2.90–4.58)	−0.64 ± 2.99 (39) (−1.61–0.33)	0.1881
Days/week you had salty snack for child to eat	2.88 ± 2.50 (50) (2.17–3.59)	3.36 ± 2.45 (39) (2.56–4.15)	0.13 ± 2.68 (39) (−0.74–1.00)	0.7665
Parent praise/encouragement for diet and/PA				
Days/week you praised child for drinking low-fat milk	0.92 ± 2.13 (50) (0.32–1.52)	2.23 ± 3.14 (39) (1.21–3.25)	1.26 ± 3.18 (39) (0.23–2.29)	0.0181*
Days/week you praised child for eating fv	2.63 ± 2.58 (49) (1.89–3.37)	4.51 ± 2.58 (39) (3.68–5.35)	1.85 ± 2.42 (39) (1.06–2.63)	<0.0001*

Table 4: Continued.

Variable	BL Mean ± Std. Dev (*n*) (95% CI)	M4 Mean ± Std. Dev (*n*) (95% CI)	Change BL to M4 Mean ± Std. Dev (*n*) (95% CI)	*P* value (2 sided)
Days/week you praised child for not drinking sweetened drinks	1.06 ± 2.26 (49) (0.41–1.71)	1.51 ± 2.43 (39) (0.73–2.30)	0.53 ± 2.48 (38) (−0.29–1.34)	0.1988
Days/week you encouraged child to watch less TV	2.40 ± 2.60 (50) (1.66–3.14)	4.31 ± 2.24 (26) (3.40–5.21)	1.35 ± 2.48 (26) (0.34–2.35)	0.0105*
Days/week you praised child for being physically active	2.88 ± 2.90 (49) (2.05–3.71)	3.54 ± 2.78 (39) (2.64–4.44)	0.49 ± 2.99 (39) (−0.48–1.46)	0.3153
Parent household rules				
Limit number of days child spends watching TV/videos	3.22 ± 1.28 (50) (2.86–3.58)	3.51 ± 1.32 (39) (3.09–3.94)	0.46 ± 1.25 (39) (0.06–0.87)	0.0271*
Limit number of days child plays video games	4.48 ± 1.76 (50) (3.98–4.98)	4.56 ± 1.70 (39) (4.01–5.11)	0.31 ± 1.70 (39) (−0.24–0.86)	0.2665
Limit number of days child spends on computer	4.54 ± 1.80 (50) (4.03–5.00)	5.00 ± 1.54 (39) (4.50–5.50)	0.56 ± 1.94 (39) (−0.07–1.19)	0.0779
Limit number of days child drinks 100% juice	2.50 ± 1.39 (50) (2.11–2.89)	3.15 ± 1.44 (39) (2.69–3.62)	0.62 ± 1.14 (39) (0.25–0.98)	0.0017
Limit number of days child eats fast food	3.82 ± 1.22 (50) (3.47–4.17)	4.44 ± 1.05 (39) (4.10–4.78)	0.69 ± 1.59 (39) (0.18–1.21)	0.0099

*Indicates significant group differences, $P < 0.05$.

should continue to acknowledge the resource limitations of low-income ethnically diverse households by strengthening these components further. Additional practical strategies that might improve intervention efficacy for low-resource households might include community gardening [57] and bonus buck programs for farmers markets [58].

Contrary to our hypotheses, we found unexpected declines in parent reports of children's outdoor playing time on both weekdays and weekend days. On average, parents reported that children participated in one hour less of total daily outdoor physical activity at the four-month follow-up assessment. These findings are disconcerting because early childhood physical activity patterns track into adulthood and high levels of physical activity in early childhood mitigate physical activity declines evidenced during adolescence [20]. The National Association for Sport and Physical Education recommends that young children (birth to age of 5) engage in 120 minutes of daily physical activity with 60 minutes of structured and 60 minutes of unstructured physical activity [59]. Parents in HHHF reported that children were physically active between 164 and 206 minutes per day. While other research findings suggest that, in the US, the majority of young children meet the daily recommendations [20, 60–62], we think the estimates from the HHHF parents are likely overestimates. Parents made anecdotal comments like "my child is hyper," and we think that they may have misjudged physical activity for motion. Other studies have also found that parents overestimate children's physical activity [63, 64]. For example, Corder et al. found that 80 percent of parents in an obesity prevention study in San Diego, California, overestimated their child's physical activity [64].

We also tested the hypothesis that seasonality may have influenced changes in outdoor physical activity from baseline to four months. There were no significant differences in baseline physical activity (weekday or weekend) between summer/early fall relative to fall/winter group participants. Also, seasonality did not significantly affect changes in weekday outdoor physical activity ($P = 0.238$). The lack of significance for weekday activity may have been mitigated by daycare/school recess and outdoor physical activity polices. However, participants who were assessed at four-month follow-up during the late fall experienced significantly larger declines in minutes of weekend outdoor physical activity relative to the group who was assessed at four-month follow-up during the winter months (−71.8 minutes relative to −12 minutes, $P = 0.408$). It is also possible that the significant reductions in physical activity observed over the course of the intervention were due to the timing (seasonality), but other explanations could also include initial overreporting of physical activity by parents and realization of this overreporting after participating in the intervention. These findings suggest that the future interventions should devote more efforts to preserving and/or increasing children's physical activity levels, especially on weekend days. In addition, future research with families of young children should not rely on self-reports but instead use objective measures such as accelerometry and give parents tailored feedback on the real activity patterns of their children.

Regarding children's sedentary behaviors, time spent watching television was significantly reduced during the weekday and somewhat declined on weekend days. Children decreased their weekday television time by almost 50 minutes from baseline to four-month follow-up but did not decrease TV time as much on weekend days. This significant reduction in TV screen time resulted in children meeting the guidelines recommended by The American Academy of Pediatrics [65] of no more than two hours of TV per day. However, there are some limitations as parents self-reported the data. Future studies might consider the use of television monitors to objectively measure whether TV use decreases [66, 67].

Research findings indicate that parental attitudes, norms, and parental screen time as well as having a television in the child's bedroom are all risk factors for increased screen time among young children [68]. Future interventions should modify these parent related behaviors and additional research should examine parent's qualitative reports to better understand the decision making processes that parents use for screen time on weekdays versus weekends.

The findings from HHHF provide mixed support for changes in parent behaviors associated with children's health behaviors. The study demonstrates favorable improvements in some of the parent behaviors related to parent role modelling, the home food environment, family encouragement for PA/diet, and household rules. Contrary to other intervention results [32, 35] however, HHHF participants did not make any significant changes in modelling of fruit and vegetable intakes or time spent being physically active with children as a family. Despite not making changes in many dietary practices, HHHF participants did report increases in role modelling of physical activity behaviors and decreases in modelling of sedentary behaviors. These results may suggest that HHHF parents felt more confident in making PA related changes than dietary changes. Future interventions with similar populations should direct more efforts to increasing parent role modelling of dietary changes and actual intakes of fruits and vegetables. Although findings are equivocal, many of the changes in parent behaviors are consistent with systematic review studies that suggest that effective parent-driven childhood obesity interventions for preschool age children incorporate behavior change strategies that are predicated on behavioral theories and include restructuring of the home environment [26, 28].

4.1. Limitations. While informative, this study is not without some limitations. The study recruited children at all levels of obesity risk, which included many children at a healthy weight and potentially more motivated parents/guardians. Additionally, as this was a pilot intervention and was underpowered to detect differences in key outcomes, the sample size was small and effect size estimates with small samples have large standard errors and wide confidence intervals. The pretest/posttest design was a limitation which might have affected the validity and generalizability of study findings [69]. This study did not include a control group, so some of the changes seen could have been due to factors other than the intervention. Also, there were no follow-up measures administered past the posttest intervention assessment so we were unable to examine whether changes were maintained over time. However, this study found significant improvements in many health behaviors related to obesity and many behavioral changes operated in the posited direction. Additionally, many of the parent related behaviors were significantly changed suggesting that the intervention favorably improved behaviors within the parents' control. Future randomized trials should be conducted with a control or comparison group to be able to assess the real effect sizes of the intervention and additional follow-up assessments to determine whether behavioral changes made during the intervention are maintained over time.

Despite the limitations, this study has a number of strengths and is one of few home-based early childhood obesity prevention interventions specifically designed for low-income diverse racial/ethnic populations. This study recruited directly from WIC clinics, thus ensuring recruitment of families who were eligible to receive income based support from federal programs. The sample was predominantly low-income and ethnically and racially diverse thus reaching populations who are at significantly higher risk for future obesity and related comorbidities. There was also good participant retention at four-month follow-up. Additionally, the goals of this intervention were aligned with current recommendations and focused on changing health behaviors for the long term instead of weight loss.

4.2. Conclusions and Next Steps. HHHF was a parent-driven home-based intervention that incorporated tailored written materials and video, nutrition information, and MI along with TV monitors and an age-matched children's exercise video. This intervention appeared to be effective in changing some aspects of children's behavior and their home environments through changes made by parents. However, a randomized trial is necessary to truly test the efficacy of this intervention. Such trial will be planned in the near future. We will also analyze correlates of children's BMI, diet, PA, and sedentary behavior as well as predictors of change, which will aid in future intervention development. Furthermore, to broaden the reach of the intervention to a larger population, we would like to be able to offer the intervention in Spanish as well as English. It may also be worthwhile to test other channels in addition to print mailings for providing tailored messages, that is, tailored video, internet, text messaging, smart phones, and etcetera. It might also be interesting to study the effectiveness of combining a home-based intervention like HHHF with a pediatric health care provider intervention or an intervention in child care settings.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Rethinking Obesity Counseling: Having the French Fry Discussion

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Childhood obesity is a complex problem that warrants early intervention. General recommendations for obesity prevention and nutrition counseling exist. However, these are notably imprecise with regard to early and targeted interventions to prevent and treat obesity in pediatric populations. This study examines family medicine primary care providers' (PCPs) perceived barriers for preventing and treating pediatric obesity and their related practice behavior during well-child visits. *Methods.* A written survey addressing perceived barriers and current practices addressing obesity at well-child visits were administered to PCPs at eleven family medicine clinics in the Duke University Health System. *Results.* The most common perceived barriers identified by PCPs to prevention or treatment of obesity in children were families not getting enough exercise (93%) and families too often having fast food meals (86%). Most PCPs do not discuss fast foods at or prior to the twelve-month well-child visit. The two-year visit is the first well-child visit at which a majority of PCPs (68%) discuss fast food. *Conclusion.* No clear consensus exists as to when PCPs should discuss fast food in early well-child checks. Previous research has shown a profound shift in children's dietary habits toward fast foods, such as French fries, that occurs between the one- and two-year well-child checks. Consideration should be given to having a "French Fry Discussion" at every twelve-month well-child care visit.

1. Introduction

Obesity is a major public health problem with over two-thirds of Americans overweight and greater than one-third obese [1]. While new data have suggested a leveling off of the prevalence of childhood obesity, 12.4% of kindergarteners are obese and overweight five-year olds are four times as likely as normal weight five-year olds to become obese [2, 3]. It has been well documented that obesity leads to cardiac, metabolic, and other systemic health derangements [4]. It has also been shown that these unfavorable changes may start as early as three years of age [5]. This emphasizes the importance of early intervention and prevention.

Well-child checks have long been recognized as opportunities to foster healthy growth and development. These regular visits, which are performed with a health care provider, traditionally occur during the newborn period, at one, two, four, six, nine, twelve, fifteen, eighteen, and twenty-four months and every year thereafter. The goal is to provide continuity of care and allow for anticipatory guidance to be given. Recognizing that diet and nutrition are linked with obesity, it is important to address these topics. However, guidelines on nutrition counseling remain vague, and visit time is constrained by a multitude of other encouraged and essential components. Yet studies show that when it comes to counseling during well-child checks, less is more and focusing on fewer topics is more effective [6].

General recommendations exist for age specific pediatric guidelines for obesity prevention and nutrition counseling. However, these are notably imprecise with regard to early and targeted interventions to prevent and treat obesity in pediatric populations.

Regarding nutrition counseling during well-child care within the first year of life, the American Academy of Pediatrics (AAP) Bright Future Guidelines contains goals for temporal introduction of foods rather than composition of diet. Even at the one-year visit, recommendations are limited to providing children with "nutritious food and healthy snacks." Surprisingly, there is no mention of nutrition guidance at the fifteen- or eighteen-month well-child checks and it is not until the two-year visit that the subject of obesity is first addressed in the guidelines [7]. Meanwhile, research shows that a rapid transition occurs between the one- and two-year well-child checks, when diet habits seemingly shift to favor fast foods, with the French fry as the number one consumed vegetable consumed by two-year olds [8].

The World Health Organization (WHO) strongly advocates for exclusive breastfeeding in the first six months of life and offers recommendations on complimentary feeding habits. These include continuing on-demand breastfeeding until two years of age and starting at 6 months of age, gradually increasing the number of feedings, consistency, and variety of other foods. For a nonbreastfed child, WHO further recommends providing four to five meals per day, with one or two healthy snacks aimed to meet the child's nutritional needs [9]. These WHO guidelines are appropriately aimed toward a global audience, with an emphasis on preventing malnutrition and ensuring adequate growth.

Current literature on prevention and treatment for obesity has overwhelmingly focused on adolescent and school aged populations. Meanwhile, diet and lifestyle habits begin to be ingrained much earlier. The AAP recommends screening for obesity starting at two years, while United States Preventive Services Task Force (USPSTF) suggests waiting until age six [7, 10]. These recommendations bypass a likely window of opportunity for primary prevention prior to the second year of life, and—in the case of the USPSTF—prior to six years.

Given these vague universal recommendations, we hypothesize that significant variability exists in clinical practice. It has been demonstrated that there is variability among pediatric primary care practices regarding obesity counseling, attitudes, and perceptions [11]. Some prior studies have focused on family medicine primary care providers' (PCPs) beliefs and practices pertaining to childhood obesity [12]. However, many of these studies have placed emphasis more specifically on evaluation of treatment modalities, perception of obesity as a disease, and physician training [13–18]. Further, much of the previous work on childhood obesity appears directed beyond the age of five years, with few interventions studied between two and six years of age [19]. A paucity of literature has focused on intervention prior to two years of age. This study builds upon the existing literature by offering a family medicine perspective and focusing specifically on perceived barriers and anticipatory guidance discussed at the early well-child checks—particularly those prior to the second year of life. This is further warranted as much of the current literature occurred prior to the updated 2008 AAP Bright Futures Guidelines [7, 20]. Given the recent emphasis on primary care and the likely influx of pediatric patients via the Accountable Care Act, family physicians will continue to provide a substantial amount of care for pediatric populations.

The goal of the present study is to assess the perception of family medicine PCPs in a university based family medicine network surrounding the barriers of preventing and treating obesity in the young child and to analyze PCPs reported behaviors at well-child checks. In addition, the present study allows for a comparison of attitudes and practice between family medicine PCPs and pediatric PCPs who participated in an earlier study using a similar survey [11].

2. Materials and Methods

2.1. Participants. The sample included all family medicine physicians, physician assistants (PAs), and nurse practitioners (NPs) at eleven family medicine Duke Primary Care sites in Duke University Health Systems.

2.2. Survey Design. The survey used in the present study was developed based on a similar study performed in pediatric practices, current epidemiological literature, and recommendations from the American Academy of Pediatrics (AAP) and the United States Preventive Services Task Force (USPSTF) [6, 10, 11]. Previous authors were contacted for permission to utilize a similar survey tool. The survey contained three independent sections, each with a brief introduction. The sections were as follows: (i) perceived barriers in treating obesity, (ii) current PCP practices at well-child checks, and (iii) demographic information.

2.3. Procedures. Eleven Duke Primary Care practices were asked and agreed to participate. Introductory phone calls with follow-up emails were sent in January 2012, prior to the in-person survey administration. An agreed upon morning or lunch hour time was arranged to include a ten-minute presentation explaining the goals of the project, with subsequent survey administration to all PCPs who attended the meetings. Written surveys were completed by the respondents anonymously and collected on site. Participation was completely voluntary and there were no financial incentives. An agreement was made to present the study findings to the participating sites at the conclusion of the study. Data collection was performed during January and February 2012 and the data were analyzed in March 2012.

2.4. Data Analytic Plan. Demographic data are presented as percentages/proportions. For questions related to perceived barriers, we calculated the percentage of respondents who indicated how important each issue was on a Likert scale 1–5 (Not Important, Slightly Important, Moderately Important, Very Important, and Critically Important), as well as the combined percentage of those who responded either Very Important (4) or Critically Important (5). For PCP behaviors assessing anticipatory guidance, multiple responses were accepted (i.e., mark all well-child checks that apply). These data are presented as percentages/proportions.

2.5. Institutional Review Board. This study was reviewed by the Research Advisory Board of the Primary Care Research Committee and the Institutional Review Board of Duke University and was found to be an exempt study (PRO00034169).

3. Results

3.1. Respondents. Surveys were completed by 56 of the 78 family medicine PCPs (41 family medicine physicians, 8 physician assistants, and 7 nurse practitioners) at the 11 participating clinics, for a 72% response rate. 55% of the respondents were female. Approximately 1/3 (35%) were 40–49 years old, 1/3 (33%) were 30–39, 27% were 50+ years old, and 5% were twenty through twenty-nine years old. The majority of PCPs were medical doctors or doctors of osteopathic medicine (MD/DO) (73%), with physician assistants and nurse practitioners making up 14% and 13%, respectively. The average reported body mass index (BMI) of respondents was 24.71 kg/m^2 (7 of the 54 respondents did not complete the BMI measures). Approximately 1/3 (33%) of the PCPs were classified as overweight and 0.6% were in the obese category. Reported BMI closely mirrored PCPs perception of their weight, as 30% indicated they were overweight and 2% believed they were obese.

3.2. Perceived Barriers to Treating Pediatric Obesity. PCPs were asked to rate the relative importance of specific barriers to preventing or treating overweight or obese children. These questions related to children of all ages and focused on many factors including the child, parents, family unit, influence of society, and PCP factors. The five barriers that were most often rated as either Very Important or Critically Important were as follows: (i) families do not get enough exercise (93%); (ii) families often have fast food meals (86%); (iii) parent is not motivated to change diet or lifestyle (81%); (iv) families watch too much TV (79%); and (v) child is not motivated to change diet or lifestyle (75%) (Table 1). The following barriers were rated as Very Important or Critically Important by 60–72% of PCPs: parent is unaware that child is overweight, parents are overweight so they are not concerned that child is overweight, families are too busy to eat home cooked meals, healthy foods are too expensive, TV advertisements promote unhealthy foods, PCPs have limited time to discuss nutrition, and PCPs are frustrated with the low success rate of treating overweight children. Barriers that PCPs were less likely to rate as Very Important or Critically Important were as follows: overweight child does not act sick, overweight child is a "good eater," parents do not have time to shop for healthier foods, families are too busy to eat meals together, healthy lifestyle habits are too complicated to follow, published reports about diet and nutrition are often confusing, school lunches promote unhealthy eating habits, PCPs' time constraints, lack of training to treat overweight children, compensation for obesity treatment, access to nutritionists, and PCPs' weight status or body mass index (Table 1).

3.3. Current Practices: Occurrence of Anticipatory Guidance. PCPs were asked to mark all of the well-child checks in which they discuss a variety of health topics with patients. Analyzing the barriers perceived by PCPs as most important to preventing and treating obesity revealed trends regarding fast food consumption and physical inactivity. As shown in Table 2, even by their own report, most PCPs did not discuss fast foods at or prior to the twelve-month visit. At the eighteen-month visit fast foods are discussed by 32% of PCPs. Meanwhile, the two-year visit is the first well-child visit at which the majority of PCPs (68%) discuss fast food. Additionally, 5% of PCPs never discuss fast food at all with families. While the majority of PCPs ultimately discuss this topic, the discussion is not undertaken by a majority of PCPs at a specific encounter until the two- through five-year visits.

Fruit and vegetable discussion increases in frequency as the child ages, with a peak of 63% of PCPs discussing this at the twelve-month visit, before dropping to 51% at the eighteen-month visit. Between 22% and 26% of PCPs discuss having 3 meals per day by the twelve-month visit, whereas 65% are discussing meal frequency at the two- through five-year visits. Physical inactivity/exercise was another area of concern with 93% of PCPs recognizing this as a contribution to obesity, yet this topic was discussed by at most 23% of PCPs at and/or before the twelve-month visit. By the eighteen-month visit, at most 48% of PCPs had ever discussed the topic with their patients or families. The two- through five-year visits are the first time at which the majority of PCPs (68%) discuss this topic. The percent of well-child visits where screen time is discussed closely mirrors physical activity/exercise, and a similar trend is seen regarding the discussion of fast foods (Table 2).

4. Discussion and Conclusions

A major finding of the current study involved the relative importance PCPs ascribe to perceived barriers in treating obesity. Our results reproduced those of a previous study utilizing a similar survey but performed within a pediatric setting [11]. Our results confirm that family medicine PCPs share the same top six concerns when dealing with perceptions surrounding obesity. These concerns center around physical inactivity, fast food consumption, and motivation to change. The barriers identified were in areas that were inconsistently addressed in practice, specifically prior to the two-year well-child check. Despite the apparent lack of congruence between the identified barriers and the actions by PCPs in clinical practice, this study is limited in being a self-reported survey. Furthermore, due to the self-reported nature, PCPs may overestimate how often they address certain issues.

A second major finding of the current study was the inconsistency PCPs demonstrated concerning when discussion took place for physical activity, fruit and vegetable selection, screen time, juice, and other beverage choices. This study suggests that primary prevention interventions targeting obesity in practice are either misplaced or missed altogether in some cases, which is consistent with other recent studies demonstrating missed opportunity for primary prevention of obesity [21–24]. As this study is representative of an academic practice population with close geographic

Table 1: Respondents' perceptions of barriers to obesity prevention or treatment in primary care, expressed as the percentage of respondents providing affirmative responses to the statement: "Please rate the importance of each of the following general barriers to preventing or treating overweight or obesity in children in your professional experience" (on a scale of importance 1–5).

	3 Moderately Important	4 Very Important	5 Critically Important	(4 + 5) Total Very and Critically Important
Parent is unaware that child is overweight	25%	47%	16%	63%
Parent is not motivated to change diet or lifestyle*	18%	40%	40%	81%
Child is not motivated to change diet or lifestyle*	16%	45%	30%	75%
Parents are overweight, so they are not concerned that child is overweight	26%	44%	28%	72%
Overweight child does not act sick	32%	32%	2%	33%
Overweight child is a "good eater"*	39%	27%	4%	30%
Parents do not have time to shop for healthier foods	28%	35%	18%	53%
Families are too busy to eat home cooked meals	21%	46%	25%	70%
Families often have fast food meals*	11%	35%	51%	86%
Families are too busy to eat meals together	30%	41%	14%	55%
Families watch too much TV*	12%	51%	28%	79%
Families do not get enough exercise*	4%	21%	71%	93%
Healthy foods are too expensive	27%	36%	34%	70%
Healthy lifestyle habits are too complicated to follow	46%	32%	5%	38%
Published reports of research studies about diet and nutrition are often confusing	35%	26%	4%	30%
TV advertisements promote unhealthy foods	23%	37%	25%	61%
School lunches promote unhealthy eating habits	39%	33%	19%	53%
PCPs have limited time to discuss nutrition	29%	36%	29%	64%
PCPs are frustrated with the low success rate of treating overweight children	25%	42%	19%	61%
PCPs lack sufficient training to help overweight children	36%	34%	11%	45%
PCPs lack sufficient education materials to prevent or treat overweight children	28%	49%	7%	56%
PCPs are not adequately compensated for treating obesity	39%	23%	16%	39%
It is difficult to convince parents to see a nutritionist	28%	42%	12%	54%
There are not enough nutritionists to help with overweight children	23%	36%	20%	55%
The PCPs weight status or body mass index	32%	13%	2%	14%

*The top 5 barriers that respondents rated as either Very Important or Critically Important.

proximity, further study on a larger scale and in other practice populations would be warranted.

The AAP recommendations make no mention of fruits and vegetables until the five- and six-year well-child visits [6]. In another case, the AAP guidelines suggest the discussion of having 3 meals per day at the nine- and twelve-month well-child checks. However, in this study, only 26% of PCPs have this discussion specifically at or before the twelve-month well-child visit. Interestingly 65% of PCPs have this discussion at the two- through five-year well-child visits despite lack of specific recommendation to do so. PCPs seem to be aware of existing guidelines but, in this example, delay the delivery.

Other than this specific recommendation at the five-year well-child visit, all of the earlier well-child visit nutrition and diet guidelines are relatively nonspecific regarding diet composition. This likely contributes toward the variability observed in this study, as many PCPs chose to have discussions, such as fruits and vegetables, at differing well-child visits. Therefore, we believe that it would be advantageous to the goals of obesity prevention and treatment to have early and targeted interventions that precede adoption of adverse lifestyle choices [25–27]. Although it is beyond the scope of this paper, innovative approaches in obesity treatment have been identified over the past decade [28–30].

Comparing this study of family medicine PCPs with a similar study done with pediatric providers revealed some similarities in practice behavior. PCPs behavior in both studies reflected the general AAP anticipatory guidance guidelines pertaining to obesity [7, 11]. However, the anticipatory guidance discussions were not consistently performed at specific visits in either study, with greater variability observed in this family practice study (see Table 2). Different methodologies were used in data collection, as the study for family medicine PCPs was measured using a cumulative approach, whereas the pediatric study was measured at point of first intervention. In comparing these studies, we chose to use the most conservative estimates by summating the

Table 2: Distribution of well-child checks at which respondents address obesity-related topics during childhood and adolescence expressed as the percentage providing affirmative responses to the question "At which well-child check(s) do you typically talk about the following? Mark all that apply."

	Newborn	2 months	4 months	6 months	12 months	18 months	2–5 years	6–11 years	12–18 years	None
Cereals	13%	20%	54%	57%	43%	25%	18%	14%	11%	2%
Juice	12%	17%	37%	62%	67%	50%	42%	31%	27%	6%
Non-juice sugar sweetened beverages	12%	10%	15%	33%	54%	44%	48%	46%	46%	6%
Fruits and vegetables	4%	7%	21%	58%	63%	51%	54%	51%	47%	2%
Sippy cups	2%	6%	15%	44%	74%	37%	17%	0%	0%	0%
Finger foods	0%	2%	11%	51%	67%	31%	13%	4%	5%	5%
Fast foods	0%	0%	4%	9%	27%	32%	68%	68%	59%	5%
Candy	0%	2%	9%	9%	34%	42%	62%	55%	43%	15%
Screen time (TV, video, video games, computer, texting)	0%	2%	4%	11%	25%	30%	71%	73%	66%	4%
Physical activity/exercise	0%	0%	0%	2%	21%	25%	68%	79%	70%	2%
Sleep	42%	39%	37%	35%	40%	39%	47%	47%	56%	5%
Having 3 meals/day (not skipping breakfast, lunch, or dinner)	0%	0%	0%	4%	22%	17%	65%	59%	63%	15%

percentages of anticipatory guidance being discussed. For example, a single PCP may have indicated that they discussed fast food at both the four- and six-month visits. Our study would count both of these as unique interventions being done by different PCPs. Consequently, these findings may offer a realistic representation or, otherwise, an overestimation of how often topics were discussed at well-child checks.

The present study identifies discrepancies in PCPs adherence to counseling guidelines for nutrition, exercise, and screen time. In regard to exercise and screen time, this study demonstrates similar increases in the percentage of PCPs discussing these topics, with the majority doing so at the two- through five-year well-child checks, and a peak between the six- through eleven-year well-child checks. However, the AAP guidelines suggest that a majority of PCPs address each of these topics much earlier. It would be beyond the scope of this discussion to address all elements of the survey. Therefore, the remainder of this discussion will focus on the results relevant to fast food counseling and nutrition and their role in obesity prevention.

A surprising result from this study was that there is no clear consensus as to when PCPs are having discussions about fast food. While a prior study indicated that 62% of pediatricians addressed fast foods at or prior to twelve-month well-child visits, this study shows that at most 39% of family physicians did so (Table 2) [11]. These estimates suggest that there is still a large percentage of the population receiving no counseling on fast food during the entire first year of life. It is not until the two-year well-child visit that a majority of PCPs discuss fast food. Meanwhile, previous research has shown that there is a profound shift in dietary habits toward fast foods, such as French fries, that occurs between the one- and two-year well-child checks [8].

To address fast food consumption, PCPs could consider integrating a universal "French Fry Discussion" regularly at the twelve-month well-child care visit. Given the recognition that food transitioning towards fast foods such as French fries occurs within the subsequent window from twelve months to twenty-four months [8], it might be beneficial to offer a specific intervention at this visit. Furthermore, prior research has shown that a dedicated intervention targeting two-year olds and their families can significantly reduce BMI [31].

The "French Fry Discussion" could take the form of a purposeful talk with family members about the importance of avoiding fast foods, fried foods, and sweetened beverages. For example, using motivational interviewing techniques has been shown to be effective in changing behavior relating to obesity, and this approach may address such a complex behavior [32, 33]. This visit could additionally include handouts or printouts about alternative foods and snacks that are affordable and can be prepared quickly. This discussion can move beyond the unidirectional lecturing that often occurs. Rather, this should be an individualized discussion, in which family members are encouraged to voice their concerns and devise solutions that meet their unique situation. As such, we would not anticipate a discussion of this relevance requiring anything less than ten minutes of dedicated visit time. The goal of this discussion would be to leverage the patient-physician-family relationship to positively impact lifestyle choices for both the child and the family. Further study is needed to examine actual obesity prevention and treatment guidelines in clinical practice and to discern the specifics, feasibility, and benefits of incorporating additional counseling into routine well-child care.

Disclosure

No competing financial interest exists.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Barriers to Lose Weight from the Perspective of Children with Overweight/Obesity and Their Parents: A Sociocultural Approach

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Introduction. There are not enough studies about the barriers to lose weight from the perspective of children and their parents. *Methods.* Children and adolescents diagnosed with overweight/obesity in the Department of Endocrinology and their parents were invited to participate in a series of focus group discussions (FGD). Twenty-nine children 10–16 years old and 22 parents participated in 7 focus groups; 2 mothers and 2 adolescents participated in depth interviews. All interviews were recorded, transcribed, and analyzed through grounded theory. *Results.* Parents went to the hospital only when their children presented any obesity complication; for them, overweight was not a health problem. Parents referred to lack of time to supervise about a healthy diet and exercise; besides, the same parents, relatives, friends, and the mass media encourage the consumption of junk food. Children accepted eating a lot, not doing exercise, skipping meals, and not understanding overweight consequences. Both, parents and children, demanded support to do the time recommended for exercise inside the schools. They also suggested getting information from schools and mass media (TV) about overweight consequences, exercise, and healthy food by health workers; they recommended prohibiting announcements about junk food and its sale. *Conclusions.* The barriers detected were lack of perception of being overweight, its identification as a disease and its consequences, lack of time to supervise a healthy lifestyle, and a big social influence to eat junk food.

1. Introduction

Rates of severe childhood obesity have tripled in the last 25 years, with significant differences by race, gender, and poverty [1]. In 2006, 70% of adults (30–60 years old) and 35% of adolescents (12–19 years old) were overweight/obese in Mexico [2], but after six years and despite different public health efforts, this high national prevalence continues [3]. A longitudinal study reported only 23% of success to decrease body mass index (BMI) in 83 of 150 adolescents who were followed during 23 months [4]. In a meta-analysis of 64 trials (5230 adolescents), authors concluded that interventions mixing lifestyle and behavior interventions were effective but need to consider psychosocial features to get behavioral changes [5]. The design of studies must consider isolation feelings, understanding of overweight consequences and comorbidities, individual barriers, and the social and cultural context [6–9].

Qualitative research has the goal of explaining the socio-cultural world through self-experience of each person acting as theoretical and methodological livelihood; use techniques and designs to get, analyze, and interpret information (narratives, videos, and documents); the results are not expressed numerically [10, 11]. Previous qualitative studies have indicated that parents are not concerned about their children being overweight. Parents have expressed more anxiety about children being underweight than overweight, so then they usually are not aware about the weight status of their children [12, 13]. By the way, children are not aware of their overweight; in fact, a qualitative study found that black female adolescents want losing weight but not too much in order not to be so different to the rest of the family [14]. In addition, parents have referred to the fact that they are depriving their children if they restrict unhealthy food [12]; they are reluctant to restrict 100% fruit juice, need specific strategies to increase vegetable consumption, and think that limiting screen time would be difficult, especially when they are busy or during inclement weather [15]. Other barriers to achieve a healthy lifestyle included cost of healthy food, time and practicality, family preferences, and difficulty in changing habits [16]; individual, family, and community involvement [17].

The aim of this study was to identify the barriers to lose weight, including the weight status perception, beliefs, habits, opinion of social support, and recommendations from the perspective of children being overweight or obese and their parents, in order to improve the interventions of overweight/obesity in children considering this information.

2. Methods

2.1. Subjects. Participants (children and parents) were recruited from a Pediatric Endocrinology Unit by a pediatrician who contacted them in the waiting area or by phone since a record of children with the diagnosis of overweight or obesity. Eligibility criteria included age (10–18 years old), male or female, overweight (body mass index (BMI) ≥ 85th percentile for age and gender) or obese (BMI ≥ 95th percentile for age and gender), and parents with a child diagnosed with overweight or obesity. The study was approved by the Research and Ethic Committee of Children's Mexico Hospital Federico Gomez and written informed consent was obtained from all parents and children.

2.2. Focus Group Methodology. A focus group is a technique of the qualitative method to describe and understand interpretations, perceptions, and beliefs of a group (6–10 persons) with a common problem [18, 19]. The goal is the heterogeneity of the information on persons who share the same problem [11, 18–20]. The theoretical sampling was selected and made according to the wealth of information and not to the number of individuals and the process stops when new more aspects of the same phenomenon are not already mentioned [11].

Focus groups were formed by a moderator-social psychologist, an observant—a physician, and 6–8 children or parents. The observant was a pediatric endocrinologist independent of his/her assigned doctors. There were 4 groups of children, 2 of girls (10–14 and 15–18 years old) and 2 of boys (10–14 and 15–18 years old), and 3 groups of parents, 2 of mothers (younger than 40 years old and older than 40 years) and 1 of fathers (every age). Four interviews were made in depth to complement the information: 2 mothers (28 and 45 years old) and 2 adolescents (girl of 13 years old and boy of 15 years old).

The guide for interview was made by literature review [5–9, 12–15] and by a research team (pediatric endocrinologist, pediatrician, psychologists, nutritionists, and medical anthropologist). The guide explored weight perception, causes of overweight, limitations to lose weight, habits and beliefs, opinions about social support, suggestions to lose weight, and the way to get more information about the health problem. The interviews lasted 90–120 minutes, were recorded, transcribed verbatim, and were run until themes based on parental and children responses achieved saturation. The analysis was made by Atlas.ti, according to grounded theory: identification of important themes, comparison of themes, and organization of each theme in families, codes, or categories [10].

Example of Coding Scheme for Theme

Limitations to lose weight are as follows:

(i) weight status perception,
(ii) weight status perception in children,
(iii) reasons to buy fast food,
(iv) limited time to prepare healthy food,
(v) limited time to be with children,
(vi) economical limitations,
(vii) poor understanding of healthy diet and habits,
(viii) poor understanding of consequences of overweight.

3. Results

3.1. Participants. Twenty-nine children and 22 parents participated in this study. The 51.7% were female and the median age was 15 years (10–17 years old). All children presented body mass index (BMI) in percentile 85 or higher. 82% of parents had overweight or obesity and only 22.7% of the children had parent participants in the focus groups. The mothers interviewed in depth were 38 and 45 years old, respectively, the girl 12 and the boy 15 years old.

3.2. Themes. We identify 4 principal themes (Figure 1): limitations to lose weight, eating and activity habits and beliefs, views on the social support, and recommendations for losing weight and disseminate information.

3.2.1. Limitations to Lose Weight

(1) Lack of Overweight/Obesity Perception. Almost all parents did not perceive overweight or obesity in their children; they went to the hospital for acanthosis nigricans, hypertension, asthma, or other health conditions but not for the weight of their children:

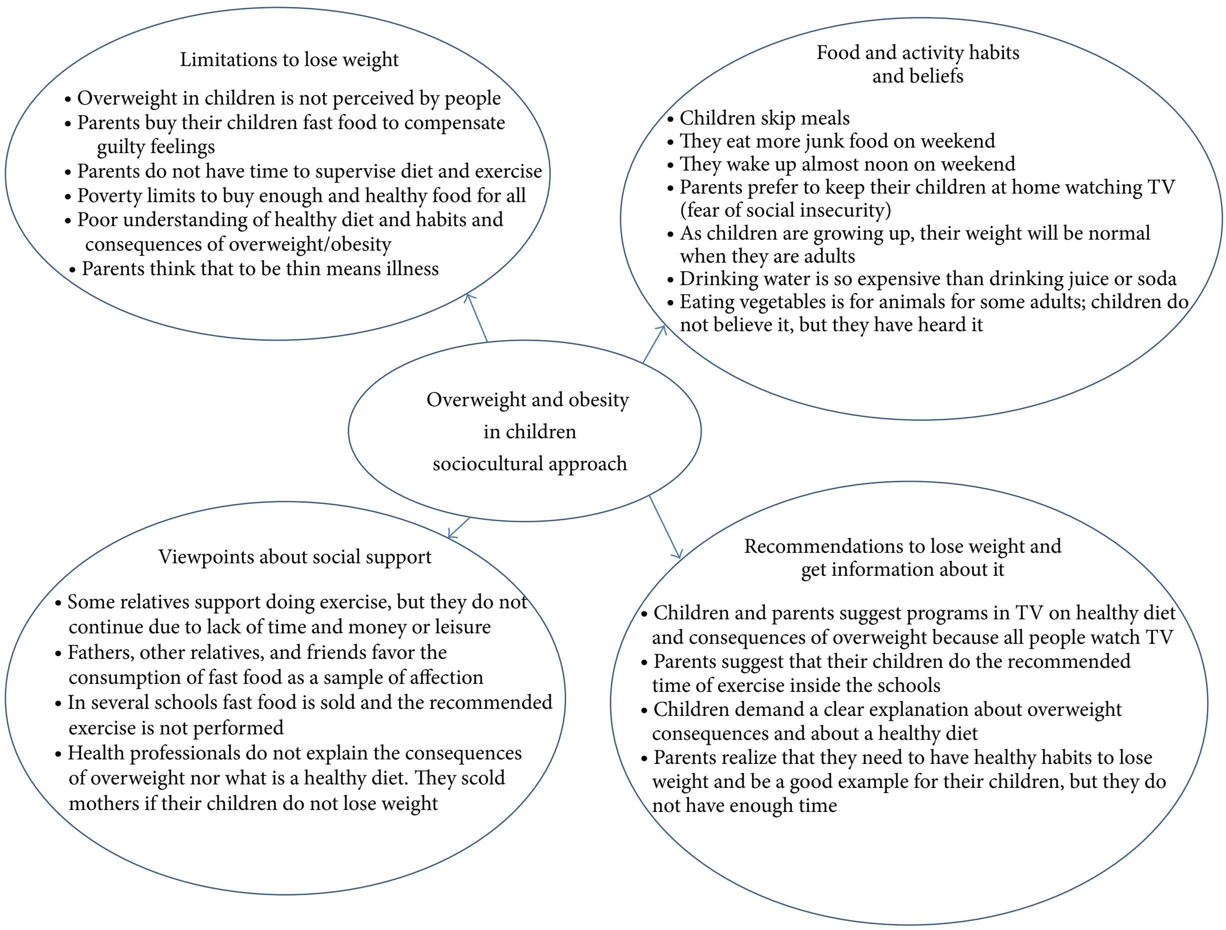

Figure 1: Sociocultural approach about overweight/obesity in children (detected barriers and recommendations from children and parents).

> *I never imagined that she was overweight... when we saw the problem of her skin... consulted a dermatologist and because of the dark neck, told us that she had to go with an endocrinologist...* (Mother, 38 years old).

(2) Guilt about Abandoning Their Children. Parents expressed feelings of guilt about leaving their children for a long time for their work and compensating them with a lot of food that they like, videogames, or anything that children demand:

> *... His dad thinks that it is giving back to the girl, the fact that it is not a lot of time with her: - Daugther [sic], these are for you, some cookies, small cakes, pizza, Chicken Happy-* (Mother, 42 years old).

(3) Lack of Time to Supervise the Children. Mothers do not have time to supervise diet and exercise of their children; some of the mothers offer their children fruits and vegetables but they do not eat them:

> *... I cannot leave work... I want to be all the time with her and really be supervising it* (Mother, 42 years old).
>
> *I find the rotting fruit of a very long time...* (Mother, 46 years old).

(4) Economical Limitations. The parents do not have enough money to buy fruit or healthier food for each member of the family:

> *What concerns me more is the economic part I think that's why I cannot give everyone all the fruits required... it does not reach... are five meals, ... three or more fruits and vegetables...* (Mother, 43 years old).

(5) Lack of Information about Healthier Food and Overweight/Obesity Consequences. Parents and children did not have an understanding of healthy diet and consequences of overweight because they did not receive a complete explanation about it in the past:

> *I had been carrying with several doctors and did not allow him to be a diet so well what it is like now that you say, such a thing is worth so many calories and you can eat as many servings...* (Father interviewed).

3.2.2. Eating and Activity Habits and Beliefs

(1) Skipping Breakfast or Any Other Time of Food. Most of the children participants did not have breakfast due to lack of time or appetite, as well as lunch or dinner:

> *. . . I only had time wash up, I did not have time for breakfast and in my school I did not eat, until I were returning home on the night I took dinner* (Female adolescent, 16 years old).

(2) Insufficient Rest (Short Sleep). Children go to bed very late because they arrive late at home, do homework, use the computer, play videogames, watch TV, or wait for their parents to come back from their job.

(3) Disorder on Weekends. Children and even parents wake up almost at noon, do not respect schedules or quality of their food, do not combine correctly the food groups or their quantities, and usually underestimate the amount of food:

> *The* ***only*** *thing that I eat in the evening it is* ***one liter*** *of milk and two loaves of bread* (Adolescent male, 16 years old).

(4) Lack of Security, Money, and Time to Do Exercise. For parents it is better that the children are entertained watching TV than in the street exposed to danger; this way, the parents are able to finish work at home. Children mentioned lack of time, nearer places, and money:

> *. . . Is the lack of time. . . and the other is the insecurity. . . if you are not with the children is very dangerous, it is the main factor in that the children are locked up* (Father interviewed).

> *Comfort for ourselves, if they are entertained watching TV, they are not giving us problems; and we can finish our tasks home. . .* (Mother, 29 years old).

> *I practiced Zumba, arabic dance and hawaiian. . . but the teachers are no longer going, I was in karate, but by issues of money, I couldn't continue. I was swimming but now for my school I do not have time to go* (Female adolescents, 10–14 years old).

(5) Practicality and Rejection of the Natural Water. Several parents said that buying a soda is cheaper and faster than preparing water with fruit. Natural water is unacceptable for several people. "*. . . my husband tells me that doing water with fruits is more expensive that buying soda. . . the water, sugar, fruits.*" "*At home it is a sin eating accompanied with natural water, poor children, how is possible they drink natural water with the food. . .*" (Focus group of mothers younger than 40 years old).

(6) Refusal to Eat Vegetables. The belief "vegetables for animals" was not present in adolescents participants, but some of them have heard it from grandparents, parents, or friends of their parents. "*A friend of mom, was eating and told than the lettuce is for animals*" (Boy, 13 years old).

(7) "Children in Growth Should Not Restrict Their Food." Some mothers expressed the idea that children should eat a lot because they are growing. In fact, they expressed that thinness indicates disease and overweight means good health. Adolescents do not share this belief but do not want to be too thin.

> *It was normal to listen-Pretty child, he is cute so chubby-. . .. When children are heavy, we are happy. . . when people saw my daughter so small and thin, they told me - your child is underweight, she looks sick. . .* (Father and mother, 42 years old, resp.).

> *. . . I would like to be thin, but not too much* (All male adolescents, 10–14 years old).

3.2.3. Views on the Social Support (Relatives, Friends, etc.)

(1) Giving Junk Food in Excess as a Display of Affection. Fathers, friends, and mass media improve excessive junk food consumption as a display of affection. "*. . . my daughter received a box of chocolate candies when she was operated. . ..*" "*When we lived in the house of my parents, they told us - How is possible that my grand-daughter does not eat sweets, this is traumatic*" (Focus group of mothers ≥ 40 years old).

> *. . . because my sons watch toys in the announcement TV of any food and they tell me buy me it or that. . ... With this type of announcementes [sic] call children, with offerings such as buy 1 and take 2, my son tell me—it is cheap -* (Mothers < 40 years old).

(2) Poor Support from Schools. In several schools fast food is sold; in fact, there are no options to eat healthy food. "*. . . In the school, there is a specific place to sell maruchan soup and it is the first to be sold, fruits and vegetables are not sold, only maruchan soup, cookies, snacks and sweets*" (Female adolescent, 13 years old).

(3) Lack of Clear Information about Obesity Consequences and Healthy Diet. Physicians do not explain enough the consequences of obesity and the meaning of a healthy diet. In addition, they scold mothers if their children do not lose weight, although some teens prefer that their doctors speak hardly about consequences in order to understand why they need to change. "*. . . physicians do not explain us the things. . . a pediatrician told me the true but very kindly, the other pediatrician told me very serious the true and now I am changing*" (Male adolescent 15 years old).

3.2.4. Recommendations to Lose Weight and Disseminate Information

(1) Support from TV and Mass Media to Disseminate Information and Regulate Publicity of Junk Food. Children and

parents recommended TV programs about healthy diet and consequences of overweight because all people watch TV. "*... more information in TV because it is the principal mass media, in TV, the experts must explain about diseases caused by the overweight...*" (Mother, 38 years old).

(2) Real Support from Schools. Parents considered that the school must also educate children about healthy lifestyle because children stay there most of their time. Children also were interested to learn about healthy food and overweight consequences in the school, by health workers. They recommended prohibiting the selling of fast and junk food and placing dining rooms offering healthy food. They also suggested that children do exercise on recommended time inside schools: *"The actions should be directed in the schools because it is where children are the greatest time..."* (Focus group of fathers).

(3) Example from Parents. Parents realize they must practice being a good example. *"I feel that if I lose weight, it would be the best motivation for my son"* (Mother, 36 years old).

4. Discussion

The lack of perception of overweight/obesity and of its condition as a disease with comorbidities favors the poor adherence to treatment [21]. In Canada, some authors reported that more than 44% underestimated children body size and also 33% of their physician [22]. Between 32.1 and 87.5% of mothers perceive the weight of their children who present overweight or obesity as normal [23–25]. The parents of this study accepted that they themselves, relatives, and friends believed that being thin means disease or debility; it is the reason why everyone recommends eating a lot to gain weight if the children were thin. Despite the fact that children participants have listened to this idea from some adults, they said they did not agree; however, they expressed wanting to lose weight but not too much although their weight was excessive. It is also possible that Mexican children do not want to lose a lot of weight in order not to be so different to the rest of the family, same as a qualitative study reported it [14] if we consider that 70% of adults in Mexico are overweight or obese. If the health personnel do not identify this lack of perception of overweight and its comorbidities, the interventions will continue without success. Mexico, until 1988, had a very high prevalence of underweight in children, so then it is also possible that people prefer to see children overweight than underweight. This low perception of being overweight and knowledge about its consequences were also recently reported in USA [26].

On the other hand, the principal limitation referred by parents was the lack of time to supervise their children; several studies have reported that the active family participation (principally parents) encourages the change toward healthy habits in children [27, 28]. In fact, in people with diabetes, family support is frequently recognized as an important factor in lifestyle changes, but only 13% of the respondents with diabetes reported that their families had made any adjustments to their lifestyles that would benefit them [29]. The same parents participants realize that if they lose weight, their children will also lose weight, as Braet has referred about the importance of telling the children "do as I do" in place of saying "do as I say" [30].

Another important barrier is the lack of understanding about overweight consequences. In fact, all parents and children participants, especially, the oldest, demanded a clear explanation about it. This clear explanation would be the best strategy to motivate parents and children to lose weight [25] and to forget the belief in adults about association between underweight and disease or overweight and good health. In a previous study, authors found that one of the reasons why children and adolescents would participate in a program to lose weight is to prevent diabetes [26]. Bolling et al. [15] interviewed parents of preschool children with overweight/obesity and they expressed, such as our participants, their interest to understand clearly the health risks being overweight and obese because it is not easy to discuss with children the importance of eating vegetables and watch TV for less time.

Parents feel guilty leaving their children alone for their jobs and, as compensation, they buy them junk food. In addition, this sense of guilt also limits their authority even more if the same parents are unable to follow a healthy lifestyle [28, 30]. Parents reported that children got angry when they were restricted to eat certain foods or demanded to do exercise [31]; one of the participating mothers said that she and her daughter consult a psychologist to improve their relationship; they have serious differences regarding food. In fact, recently, in a qualitative study of Mexican-American and Mexican immigrant, the majority of parents described being permissive and allowing unhealthy food choices [32]. Usually, when people are imposed to change, without the freedom to make their own choices, this makes it totally the opposite, so it is important to make sure that the child wants to change and is willing to do so [33].

Several authors have reported, from the perspective of physicians interviewed, that the therapeutic success is low because patients and relatives do not have motivation, there is no family support, the mass media influence their elections of food, and there are no brochures more comprehensive and practical on healthy eating and exercise [34–37], and just this impression was also shared by the participants (children and parents) of this study.

Interventions in secondary schools have improved the sale of food [31, 38–40], which also suggested participants in our study, in addition to install dining rooms that offer healthy and balanced meal. In fact, in the State of Mexico, two communities with similar sociodemographic characteristics were randomized to implement an intervention ($n = 816$) or serve as a control ($n = 408$). The intervention was carried out in primary schools and it consisted of education on healthy habits, modification of distributed food, and physical activity. Until after three years, intervention resulted in a lower increase of BMI (1.6 versus 1.9 Kg/m^2, $P < 0.01$) and a decreased consumption of total calories, bread, fat, and sugar consumption in the schools [41]. On the other hand, as the school is the place where children are spending a great number of hours, it is the best place to play and do physical activity with trained professionals in order to increase the playtime of children, as our participants suggested in the focus groups [42]. In fact, in Israel, Stein et al. recently published that the psychosocial mediators include the influence of the family and peer environment and exposure to the media and our participants also mentioned the big influence of TV, so then this author concluded that prevention programs should be multidisciplinary, combining the knowledge of experts from different professions and taking into consideration the important role of the family environment and relevant influential social organizations, particularly school [43].

The principal limitation of this study was at the same time a stronghold because our participants were already alive to the problem. In the past, they did not perceive the overweight in their children, did not identify it as a disease, and ignored the consequences and the best way to eat; now, they had more knowledge to give recommendations in order to decrease the weight. However, the perspective could be a little different, interviewing people without the perception of overweight/obesity in children and their parents.

In conclusion, the barriers detected in this study have similitude and differences with other big cities. The intervention programs must consider the lack of perception of being overweight/obese, its identification as a disease, and its consequences; the lack of time of parents to supervise diet and exercise of their children; the great influence of relatives, friends, school, and mass media to eat junk food and the possibility to educate about it from schools and mass media (principally TV) by health personnel.

Conflict of Interests

None of the authors have any conflict of interests to report and none of this data has been previously published.

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Review Article

Maternal Weight Gain in Pregnancy and Risk of Obesity among Offspring: A Systematic Review

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Objectives. To systematically review the evidence from prospective and retrospective cohort studies on the association between gestational weight gain (GWG) and offspring's body weight. *Methods*. Electronic databases PubMed, Web of Science, CINAHL, and Academic Search Premiere were searched from inception through March 18, 2013. Included studies ($n = 23$) were English articles that examined the independent associations of GWG with body mass index (BMI) and/or overweight status in the offspring aged 2 to 18.9 years. Two authors independently extracted the data and assessed methodological quality of the included studies. *Results*. Evidence from cohort studies supports that total GWG and exceeding the Institute of Medicine maternal weight gain recommendation were associated with higher BMI z-score and elevated risk of overweight or obesity in offspring. The evidence of high rate of GWG during early- and mid-pregnancy is suggestive. Additionally, the evidence on inadequate GWG and net GWG in relation to body weight outcomes in offspring is insufficient to draw conclusions. *Conclusions*. These findings suggest that GWG is a potential risk factor for childhood obesity. However, findings should be interpreted with caution due to measurement issues of GWG and potential confounding effects of shared familial characteristics (i.e., genetics and maternal and child's lifestyle factors).

1. Introduction

Childhood obesity is a pandemic [1]. Over 155 million children aged 5–17 are overweight or obese worldwide [2]. In the United States, 16.9% children and adolescents aged 2–19 years are obese [3], while, in Europe, 12–36% children aged 7–11 years are overweight or obese. The childhood obesity epidemic has become a public health priority because of its immediate health consequences for children such as increased risk of type 2 diabetes mellitus and heart diseases [4, 5] and its long-term health impact such as increased risks of cardiovascular diseases, cancers and all-cause mortality in adulthood [6–8].

To reverse the obesity epidemic among children, identifying risk factors for prevention is crucial. Obesity is a result of individuals consuming more energy than they expend [9]. This positive energy balance is subject to multiple factors such as genetics, environment, and lifestyle factors [10–12]. In recent years, a growing body of literature suggests that intrauterine environment may also have a profound influence on the development of obesity later in life [13, 14]. One possible mechanism is that a suboptimal intrauterine nutritional environment that may modulate child's energy balance system through altering the developmental programming of appetite control and the metabolism of adiposity and adipocytes in fetuses. Children with the modified energy balance systems may be more vulnerable to obesogenic environment and thus increasing their risk of developing obesity in childhood [13, 14].

Maternal gestational weight gain (GWG), defined as the amount of weight a pregnant woman gained between the time of conception and the onset of labor [15], is one of the key markers of intrauterine nutritional environment. Between 1997 and 2007, approximately 46% of the pregnant US women gained more weight than the Institute of Medicine (IOM) recommendation [16, 17].

In recent years, this health issue has attracted an increasing number of researchers due to the potential impact of GWG on offspring's body weight in childhood [16–18]. Therefore, the objective of this review was to systematically summarize current knowledge regarding the association between GWG and offspring body weight in children aged 2 to 18.9 years from observational studies.

2. Materials and Methods

2.1. Search Strategy. A systematic review of existing cohort studies (prospective and retrospective) was performed following the PRISMA (preferred reporting items for systematic reviews and meta-analysis) statement [19] (see Supplementary Table 1 available online at http://dx.doi.org/10.1155/2014/524939) and the MOOSE (meta-analysis of observational studies in epidemiology) [20] guidelines. One author (EYL) conducted an electronic database search to retrieve English articles from PubMed, Web of Science, CINAHL, and Academic Search Premiere published from inception to March 18, 2013. The search strategies combined "gestational weight gain" or "pregnancy" or "maternal weight gain" with any of the following terms: outcomes (overweight, obesity, adiposity, or body mass index), target population (child, adolescent, offspring), and study design (longitudinal studies, cohort studies, or follow-up studies). Full electronic search strategies were described in Supplementary Table 2. To attain additional eligible articles, experts in the field were contacted; reference lists of located studies and relevant reviews [21, 22] were scanned. The search was limited to English articles published in international peer-reviewed journals. Book chapters, abstracts of conference proceeding, and dissertations were excluded.

2.2. Selection of Studies. To be included, articles had to (1) employ a cohort study design (prospective and retrospective), (2) focus on children aged 2 to 18.9 years, and (3) use GWG as an exposure and child age-and-gender specific BMI or overweight status used as an outcome. The current review focused on studies conducted in children and adolescents aged 2 to 18.9 years because the BMI-for-age percentiles from the Centers for Disease Control and Disease Prevention (CDC) and the International Obesity Task Force (IOTF) all start at age 2. BMI-for-age and overweight status were selected as the primary outcomes of interest because they were widely used in existing studies. Fat mass or waist circumference was not chosen because very few studies focused on these outcomes [23–25]. Studies were excluded if they focused on GWG in relation to child birth weight [26–28] or if the studies examined maternal prepregnancy overweight status rather than GWG in relation to offspring's body composition outcomes [29, 30].

The results from each database search and hand search were entered into Endnote database (Endnote X6, Thomas Reuters, 2012) and duplicated studies were removed. The title and abstract of the remaining studies were screened to identify potential articles for independent assessment of eligibility by two authors (EYL, JXL) and checked by the third author (JHL). Any disagreements were resolved by discussion among authors.

2.3. Data Analysis. The following data were extracted into a summary table by one author (EYL) and checked by another author (JXL): source (year of publication and country in which study was conducted); study characteristics (sample size, time period of the cohort, and child age at follow-up); GWG and child body weight measurements; confounders adjusted; and main findings. We decided not to use formal meta-analytic methods to estimate the effect of the exposure because of the expected heterogeneity in included studies, such as variations in exposure measures, length of follow-up, study population, and analytical methods. Therefore, the present review provided a qualitative evaluation of the longitudinal association between weight gain during pregnancy and child body weight outcomes. When a study presented results of multivariable statistical models, we summarized the findings based on the fully adjusted models. Discrepancies in data extraction were resolved by consensus of all authors.

2.3.1. Methodological Quality Assessment. Two authors (EYL and JXL) independently rated the quality of included studies using an 8-item quality assessment checklist based on a published scale [15]. The quality of each study was graded as high, medium, or low on each of the following domains: background and objective, sample selection, specification of exposure, specification of outcome, data source, follow-up, comparability of analysis, analysis of outcome, and result interpretations.

3. Results

3.1. Summary of the Search. The literature search yielded 2,869 hits. After eliminating 909 duplicates, 2,206 articles were screened by titles and abstracts. An additional 2,148 articles were excluded for not meeting our inclusion criteria. The remaining eligible full-texts articles ($n = 58$) were carefully reviewed and 38 of these articles were excluded due to (1) inclusion of samples outside targeted age range ($n = 2$), (2) not using a cohort study design ($n = 1$), (3) not using child BMI or overweight status as an outcome ($n = 12$), and (4) not using GWG as an exposure ($n = 21$). As a final step, contacting expert in the field and screening reference lists of eligible studies ($n = 18$) yielded an additional article [31]. Thus, a total of 23 articles [23–25, 31–50] were included in the systematic review (Figure 1).

3.2. Characteristics of Included Studies. Study characteristics are presented in Table 1. Fifteen studies [23–25, 32, 33, 35, 39–45, 47, 50] were based on a pregnancy cohort in which pregnant women were recruited during pregnancy and their offspring were followed prospectively during the childhood [51]. Six studies [34, 36–38, 46, 49] used mixed prospective cohort designs, in which maternal GWG was ascertained

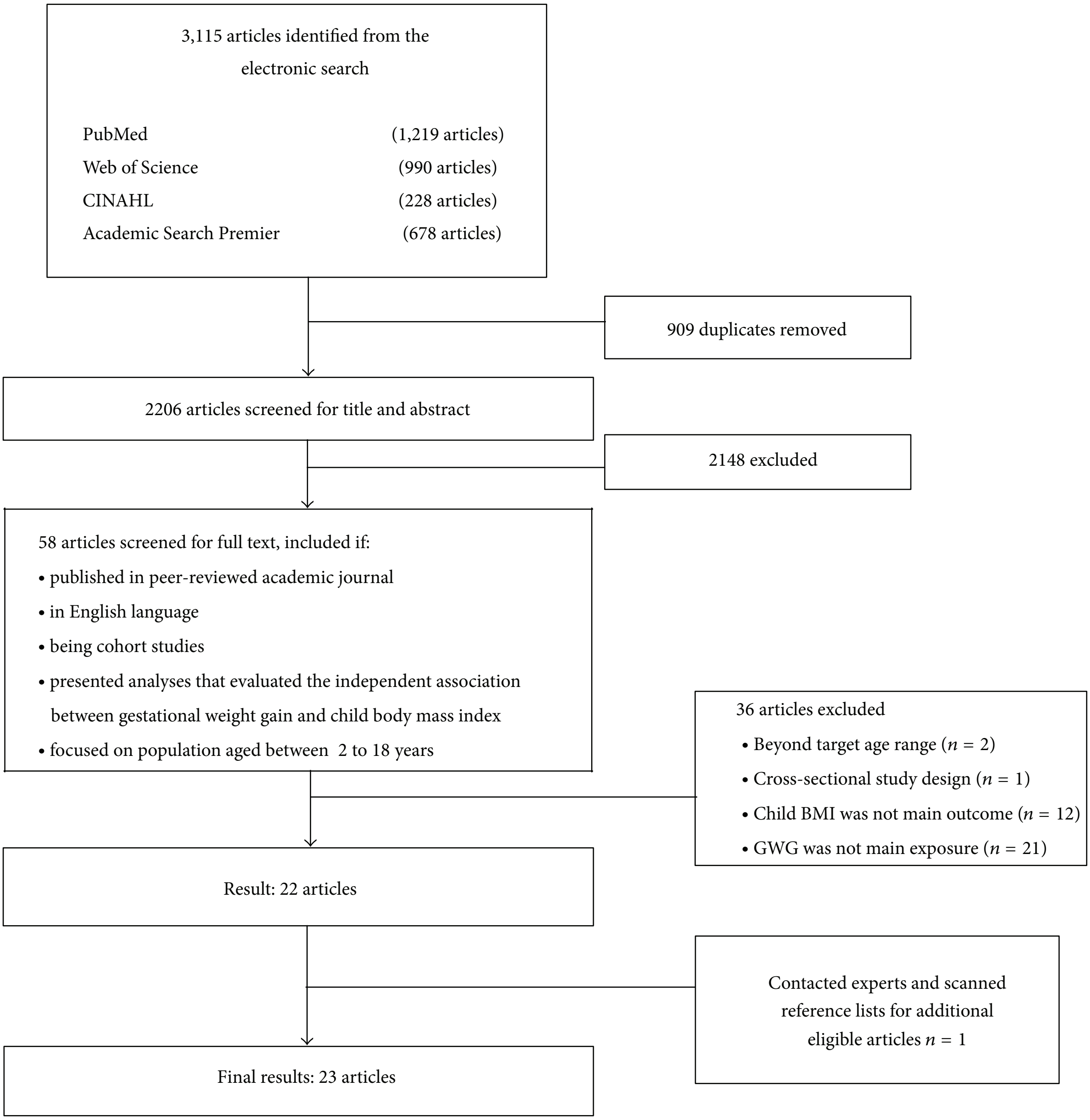

Figure 1: Flow diagram of study selection process.

from medical records, and child's body weight was collected during the follow-up [51]. Three studies [31, 43, 48] used a retrospective design, in which maternal GWG was obtained from past records and data on child's body weight outcomes were either retrieved from medical record or ascertained at the time the study began [51].

Nine out of the 19 studies used data from historic cohorts (i.e., cohorts initiated between 1959 and 1990) [24, 33, 37–39, 43, 44, 46, 47]. Sixteen studies were conducted in the US [25, 31, 33, 35, 36, 38–43, 46–50] and seven studies in Europe [23, 24, 32, 34, 37, 44, 45]. Most of these studies included a reasonably large sample size ($n \geq 1000$) with three exceptions ($n < 700$) [42, 43, 49]. Studies conducted in Europe and the US mainly enrolled Caucasian women; all but two [37, 46] enrolled both male and female offspring. Twelve studies focused on younger children (aged 3 to 5 years) [25, 33–36, 39, 40, 42, 43, 45, 48, 50], four studies on older children (aged 6 to 12 years) [23, 32, 46, 47], and three studies concentrated on adolescents (aged 13 to 18 years) [24, 37, 41]. Three studies examined the association of interest across age groups [31, 38, 44].

Three articles came from the Project Viva [25, 35, 40] and were treated as separate studies because they examined different GWG exposures. Two studies [33, 47] drew data from the National Collaborative Perinatal Project and were both included as separate studies because Branum et al. [33] focused on family groups to control for shared genetic or environmental factors. Two articles [42, 50] used data

Table 1: Cohort studies on maternal weight gain during pregnancy and offspring's body weight outcomes.

Authors, year, country, and study design	Sample size and time period	Child age at follow-up	Definition of gestational weight gain (GWG)	GWG variable	Child body weight measure	Confounders adjusted
Li et al. 2007, USA (mixed) [38]	1,739 (1986–2000)	2–12 years	Self-reported weight before delivery minus self-reported prepregnancy weight	Total GWG (kg) (i) <6.8 (ii) 6.81–11.34 (iii) 11.35–15.88 (ref) (iv) 15.89–20.42 (v) ≥20.43	BMI z-score based on measured height and weight Early-onset OW: BMI ≥95th PCTL persisted from 2 to 8 years Late-onset OW: BMI ≥95th PCTL starting at 8 years (CDC)	Maternal age, alcohol consumption during pregnancy, education, family net income0 and prepregnancy BMI, and smoking during pregnancy; child's birth order, birth weight, birth year, breastfeeding, gestational age, race, and sex
Oken et al. 2007, USA (pros) [25]	1,044 (1999–2002)	3 years	Medical record retrieved last prenatal weight minus self-reported prepregnancy weight	Total GWG (kg) Net GWG (total GWG minus infant birth weight) IOM 1990 (i) Excessive (ii) Adequate (iii) Inadequate (ref)	BMI z-score based on measured height and weight OW: BMI ≥95th PCTL (CDC)	Mother's glucose tolerance, marital status, prepregnancy BMI, SES, smoking, and race; paternal BMI; and child breastfeeding duration, cesarean section, daily television viewing time, fast food and sugar beverage intake, gestational fetal growth, gestational length, and sex
Gillman et al. 2008, USA (pros) [35]	1,110 (1999–2002)	3 years	Medical record retrieved last prenatal weight minus prepregnancy weight	IOM 1990 (i) Excessive (ii) Nonexcessive (Ref)	BMI z-score based on self-reported height and weight OW: BMI ≥95th PCTL (CDC)	Maternal education, prepregnancy BMI, smoking during pregnancy, and SES; child breastfeeding duration, daily sleep during infancy, and race
Oken et al. 2008, USA (pros) [41]	11,994 (1996–1999)	9–14 years	Self-reported total GWG	Total GWG (lbs) IOM 1990 (i) Excessive (ii) Adequate (Ref) (iii) Inadequate	BMI z-score based on self-reported height and weight OW: BMI 85th to ≤95th PCTL OB: BMI >95th PCTL (CDC)	Maternal age, education, SES, gestational diabetes, marital status, prepregnancy BMI, smoking, and paternal education; and child age in 1996, birth weight, breastfeeding, daily sugar sweetened beverage intake, fried food away from home, gestational age, maturity, hours of TV and video, physical activity, and race
Wrotniak et al. 2008, USA (pros) [47]	10,226 (1959–1965)	7 years	Weight measured at delivery minus self-reported prepregnancy weight	Total GWG (kg) IOM 1990 (i) Excessive (ii) Adequate (Ref) (iii) Inadequate	BMI z-score based on measured height and weight OW: BMI ≥95th PCTL (CDC)	Maternal age, prepregnancy BMI, parity, race, and smoking; child age at 7-year assessment, birth weight, gestational age, and sex
Oken et al. 2009, USA (pros) [40]	2,012 (1999–2002)	3 years	Medical record retrieved last prenatal weight minus self-reported prepregnancy weight	Rate of GWG (kg/week)	BM z-score based on measured height and weight OB: BMI >95th PCTL (CDC)	Prepregnancy BMI
Olson et al. 2009, 2010, USA (pros) [42, 50]	321 (1997-1998)	4 years	Measured weight at last prenatal visit minus first measured weight in the first trimester	Net GWG (kg)	BMI z-score based on self-reported height and weight OW: BMI 85th to <95th PCTL OB: BMI ≥95th PCTL (CDC)	Maternal overweight at early pregnancy, SES, smoking during pregnancy, and SES; child birth weight, breastfeeding for at least 6 months, and gestational age
Stuebe et al. 2009, USA (mixed) [46]	26,506 (1989–2001)	7 years	Self-reported total GWG	Total GWG (lbs) (i) <10 (ii) 10–14 (iii) 15–19 (Ref) (iv) 20–29 (v) 30–40 (vi) >40	BMI based on measured height and weight OW: BMI ≥25 to <30 kg/m^2 OB: BMI >30 kg/m^2 (CDC)	Maternal age at child birth, prepregnancy BMI, maternal age at child's birth, nausea and smoking during pregnancy, family history of diabetes, parental BMI and education level, and mother living with father at time of child's birth; child birth weight and birth order
Fraser et al. 2010, UK (pros) [23]	5,154 (1991-1992)	9 years	Measured weight at last prenatal visit minus measured weight at first prenatal visit	Rates of GWG (g/week) IOM 2009 (i) Excessive (ii) Adequate (Ref) (iii) Inadequate	BMI based on measured height and weight (IOTF)	Maternal age, delivery mode, parity, prepregnancy BMI, parity, smoking during pregnancy, SES, and GWG in the previous pregnancy; child birth weight and gestational age
Magerison Zilko et al. 2010, USA (retro) [31]	4496 (1972–2000)	2–20 years	Self-reported weight at delivery minus self-reported prepregnancy weight	Total GWG (kg) IOM (2009) (i) Excessive (ii) Adequate (Ref) (iii) Inadequate	BMI z-score based on parent-reported or measured height and weight OW: BMI ≥85th PCTL (CDC)	Maternal age, education, poverty status, length of gestation, prepregnancy BMI, and race, smoking during pregnancy; child sex and year of birth; and weighted for sampling proportion

Table 1: Continued.

Authors, year, country, and study design	Sample size and time period	Child age at follow-up	Definition of gestational weight gain (GWG)	GWG variable	Child body weight measure	Confounders adjusted
Schack-Nielsen et al. 2010, Denmark (pros) [44]	4,234 (1959–1961)	1–14 years	Self-reported total GWG	Total GWG (kg) (i) <6 (ii) 6–8 (iii) 9–10 (iv) 11-12 (v) 13–15 (vi) ≥16 kg The values of 5.5, 7.0, 9.5, 11.5, 14.0, and 16.5 were assigned mid-points to get continuous GWG	BMI z-score based on measured height and weight (British 1990 growth chart)	Maternal age, edema during prepregnancy, marital status, SES, and smoking during pregnancy; parental education, prepregnancy BMI, and prematurity; and child birth weight, gestational age, and sex
Andersen et al. 2011, Denmark (pros) [32]	9,869 (1996–2002)	7 years	Self-reported total GWG	Total GWG rates of GWG [kg in early (12–20 weeks) and mid-pregnancy (25–32 weeks)]	BMI z-score based on parent-reported height and weight (IOTF)	Maternal age, parity, smoking during pregnancy, prepregnancy BMI, SES, and paternal BMI; child age, birth weight, breastfeeding, gestational age, weight at 5 and 12 months, and sex
Branum et al. 2011, USA (pros) [33]	5,917 (1959–1965)	4 years	Measured weight at last prenatal visit within 3 wk of delivery minus self-reported prepregnancy weight	Total GWG IOM 1990 (i) Excessive (ii) Adequate (Ref) (iii) Inadequate	BMI z-score based on measured height and weight (CDC)	Maternal age, parity, prepregnancy BMI, race, SES, and smoking; child birth weight, gestational age, and sex
Lawlor et al. 2011, Sweden (mixed) [37]	14,6894 (1973–2005)	18 years	Measured weight within 12 h after delivery minus the first antenatal clinic assessment (~10 wk gestation)	Net GWG (kg)	BMI based on measured height and weight (CDC)	Maternal age, education, gestational diabetes, parity, and early-pregnancy BMI; child birth weight, gestational age, and year of birth
Ronney et al. 2011, USA (retro) [43]	450 (1988)	4-5 years	Measured weight prior to delivery minus self-reported prepregnancy weight	IOM 1990 (i) Excessive (ii) Adequate (Ref) (iii) Inadequate	BMI z-score based on measured height and weight OB: ≥85th PCTL	Maternal marital status, GWG in first 4 months and smoking, during pregnancy; child insurance status at birth and sex
Ensenauer et al. 2013, Germany (mixed) [34]	6,837 (2009–2011)	5 years	Measured weight at an average of 38-wk of gestation minus measured prepregnancy weight	Total GWG IOM 2009 (i) Excessive (ii) Adequate (Ref) (iii) Inadequate	BMI z-score based on measured height and weight OW: BMI ≥90th PCTL. OB: BMI ≥97th PCTL (IOTF)	Maternal age and smoking during pregnancy; child age, birth weight, breastfeeding, TV viewing, physical activity, and SES
Hinkle et al. 2012, USA (mixed) [36]	3,600 (2001–2006)	5 years	Total GWG from birth certificates (81%) plus maternal report (19%) at 9-month postpartum	Total GWG (kg)	BMI z-score based on measured height and weight OW: BMI 85th to <95th PCTL. OB: BMI ≥95th PCTL (CDC)	Maternal age, race, parity, marital status, education, participation in special supplement nutrition program for women and child, smoking at the last 3 months of pregnancy, and postpartum exercise habits; child's exercise habit; and child birth weight, breastfeeding, gestational age, sugar-sweetened beverage intake, fast food intake, and TV viewing
Laitinen et al. 2012, Finland (pros) [24]	6,637 (1985–2002)	16 years	Measured weight at 20-wk gestation minus self-reported prepregnancy weight	GWG at 20-week gestation (kg) (quartiles were used)	BMI z-score based on measured height and weight (IOTF)	Maternal education, glucose metabolism, hemoglobin at 8–10 weeks of gestation, parity, prepregnancy BMI, and smoking; child's sex
Linberg et al. 2012, USA (mixed) [49]	471 (2004)	5–8 years	Medical record retrieved weight at delivery minus recorded prepregnancy weight	IOM 2009 (i) Excessive (ii) Not excessive (Ref)	BMI z-score based on measured height and weight OW: BMI ≥85th PCTL (CDC)	Maternal education, gestational diabetes, prepregnancy BMI, and smoking before and during pregnancy; child's birth weight and breastfeeding duration
Magerison-Zilko et al. 2012, USA (pros) [39]	3,015 (1959–1967)	5 years	Medical record retrieved last prenatal weight minus self-reported prepregnancy weight	Total GWG trimester-specific rates of GWG	BMI z-score based on measured height and weight OW: BMI ≥85th PCTL (CDC)	Maternal age, education, marital status, parity, prepregnancy BMI, smoking during pregnancy, and race; paternal overweight; and child gestational age, and sex

Table 1: Continued.

Authors, year, country, and study design	Sample size and time period	Child age at follow-up	Definition of gestational weight gain (GWG)	GWG variable	Child body weight measure	Confounders adjusted
Stamnes Køpp et al. 2012, Norway (pros) [45]	5,898 (1999–2009)	3 years	Self-reported weight at 30-week pregnancy minus self-reported prepregnancy weight	GWG at 30-week gestation (kg)	BMI based on parent-reported height and weight	Maternal age, education, exercise habit, parity, prepregnancy BMI, smoking during pregnancy, and paternal BMI; child birth weight, breastfeeding at 6 month, types of day care, hours in screen-based activities, and sex
Ehrenthal et al. 2013, USA (retro) [48]	3,320 (2004–2007)	4 years	Self-reported weight at delivery minus self-reported prepregnancy weight	Net GWG (adjusted for gestational age) (kg) IOM 2009 (i) Excessive (ii) Adequate (Ref) (iii) Inadequate	BMI z-score based on medical record retrieved height and weight (CDC)	Maternal age, gestational diabetes and hypertension, insurance status, marital status, parity, preeclampsia, prepregnancy BMI, diabetes, hypertension, race, and smoking during pregnancy; child age and child born to same mother

BMI = body mass index; CDC = Center for Disease Control and Prevention; GWG = gestational weight gain; IOM = Institute of Medicine; IOTF = International Obesity Task Force; mixed = mixed cohort; NW = normal weight; OB = obese; OW = overweight; PCTL = percentile; pros = prospective cohort; Ref = referent group; retro = retrospective cohort; SES = socioeconomic status; UW = underweight; and WHO = World Health Organization.

from the Bassett Mothers Health Project; given that both investigations focused on the same GWG exposures and outcomes (but at different ages), they were combined into a single study for analyses and interpretation.

3.3. GWG Measures. GWG is a composite variable that is comprised on measurements of prepregnancy weight, weight, and gestational age at delivery. Methods used to assess GWG varied considerably across the studies. As shown in Table 1, a majority of studies defined total GWG as the difference between mother's weight at delivery or near delivery and mother's prepregnancy weight [15]. Most of the included studies used the last weight measure during prenatal care visits but did not specify the mean duration of measurement time to delivery [23, 25, 31, 35, 38–40, 42, 47–50]. Four studies reporting this information differed in the proximity of last weight measurement prior to delivery (ranged from 37 weeks of gestation to just prior to delivery) which impacts their capacity to measure total weight gain throughout the whole pregnancy [33, 34, 43]. Additionally, one study measured weight within 12 hours after delivery, not accounting for the weight of fetus [37]. Two studies measured weight at 20th week and 30th week of gestation [24, 45]. Four studies asked women to recall their total GWG at postpartum [36, 41, 44, 46]. In terms of the measurement methods, most studies used self-reported prepregnancy weight or weight data abstracted from medical records. Only three studies used objectively measured weight in the early pregnancy [23, 37, 42].

GWG was used as either continuous and/or categorical variables. As a continuous variable, GWG was mainly coded in three ways: total GWG ($n = 12$) [25, 31–34, 36, 38, 39, 41, 44, 46, 47], net GWG ($n = 5$) [25, 37, 42, 48, 50], and rate of GWG (kg or lbs/week) ($n = 4$) [23, 32, 39, 40]. Total GWG is defined as the difference between mother's weight at delivery or near delivery and her prepregnancy weight. Net GWG was calculated by subtracting infant's birth weight from the total GWG, and this accounts for the variation in infant's birth weight. Due to the variation on the timing of weight gain measurements obtained during pregnancy as well as the differences in gestational age at delivery, some studies used the weekly rate of GWG. Weekly rate of GWG is defined as total GWG divided by the duration of pregnancy, expressed as weeks of gestation for the interval such as a trimester or at the visit [39]. Two studies used GWG at 20th week [24] and 30th week [45] of gestation as the exposure. Nine studies adopted the IOM guideline (either 1990 [25, 33, 35, 41, 43, 47] or 2009 [23, 34, 49] guidelines) to categorize maternal total GWG as inadequate, adequate, or excessive GWG. Additionally, two studies analyzed maternal total GWG as a categorical variable using arbitrary cut-off points [38, 46].

3.4. Child Body Weight Measures. Child body weight outcome was expressed as BMI z-score (continuous) in 10 studies and overweight status (categorical) in 13 studies. All studies from USA ($n = 16$) followed the CDC 2000 cut-off points [25, 31, 33, 35–37, 39–42, 47–50]. Five out of the seven European studies [23, 24, 32, 34, 45] used cut-off points from IOTF/WHO growth chart; one study [44] determined the cut-off points based on national growth chart and two studies [37, 46] used BMI (weight (kg)/height (m)^2) as the outcome variable. In terms of measurement, 15 studies used objectively measured child body weight [23–25, 33, 34, 36–40, 43, 44, 46, 47, 49], four studies used self-reported [35, 41, 42, 50], and three studies used other anthropometrical measures (i.e., parental-reported [32, 45] or clinically recorded [48]). Only four studies included two or more measurement time points during the entire follow-up period [38, 42, 44, 49] and the remaining studies measured child's body weight once (Table 1).

3.4.1. Methodological Quality Assessment. Three studies [23, 37, 48] were rated as having high methodological quality and 20 studies with medium quality [24, 25, 31–36, 38–47, 49, 50]. Overall, studies did not meet the high quality category because of the use of self-reported measures on GWG and child's body weight outcomes (Table 2).

3.4.2. Total GWG and Offspring's Body Weight Outcomes. Table 3 summarized the strength of associations between various GWG measures and body weight outcomes in offspring. Seven out of eight studies [25, 32, 34, 39, 41, 44, 47] that examined the association between continuous total GWG and offspring's body weight outcomes found a significant positive association. That is, an additional kilogram increase in total GWG increased child's BMI z-score by 0.006 to 0.06 units and elevated the risk of overweight or obesity by 1% to 23% after adjusting for potential confounders (Table 3). Five studies [25, 31, 34, 36, 47] conducted stratified analyses to investigate the modifying effect of prepregnancy BMI on the association between total GWG and child's body weight outcomes (Table 4). One study [36] found that the direct effect of GWG on offspring's BMI z-score was stronger than indirect effects in normal-weight and overweight mothers.

Two studies used an arbitrary cut-off point to classify total GWG. Li et al. [38] examined total GWG in relation to the latent growth trajectory in offspring from age 2 to 12. The odds of having child with early-onset of overweight in mothers who gained ≥20.43 kg during pregnancy was 1.7 times that of mothers who gained between 11.35 and 15.88 kg (i.e., higher probability of being overweight between ages 2 and 6). However, total GWG was not associated with the late-onset of overweight in offspring (i.e., lower probability of overweight after 8 years of age). Stuebe et al. [46] categorized total GWG into <10, 10–14, 15–19, 20–29, 30–39, and ≥40 lbs. Their findings indicated a U-shape association between total GWG and offspring's weight status. Using mothers who gained 15–19 lbs as a reference group, the risk of overweight at age 18 significantly increased in offspring of mothers who gained <10 lbs (adjusted odds ratio (AOR): 1.51, 95% CI: 1.00–2.30), 10–14 lbs (AOR: 1.56, 95% CI: 1.13–2.16), and ≥40 lbs (AOR: 1.68, 95% CI: 1.13–2.52).

3.4.3. Net GWG and Offspring's Body Weight Outcomes. Less evidence exists for an association between net GWG and child's body weight outcomes. Four studies [25, 31, 37, 48] demonstrated a positive relationship between net GWG and

Table 2: Methodological quality assessment of included cohort studies.

	Li et al. [38]	Oken, et al. 2007 [25]	Gillman et al. [35]	Oken, et al. 2008 [41]	Wrotniak et al. [47]	Oken, et al. 2009 [40]	Olson et al. [42, 50]	Steube et al. [46]	Fraser et al. [23]	Magerison Zilko et al. [31]	Schack-Nielsen et al. [44]	Andersen et al. [32]	Branum et al. [33]	Lawlor et al. [37]	Rooney et al. [43]	Ensenauer et al. [34]	Hinkle et al. [36]	Laitinen et al. [24]	Lindberg et al. [49]	Magerison-Zilko et al. [39]	Stamens-Køpp et al. [45]	Ehrenthal et al. [48]
(1) Description of background Presented in context of previous research, hypothesis clearly described. √: 2 elements, O: 1 element, and X: 0 element presented	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
(2) Sample definition Explicit inclusion/exclusion criteria, uniform application of criteria, clear description of recruitment strategy and participant's characteristics, power analysis, or some other basis noted for determining the adequacy of study sample size. √: >3 or more elements, O: 2 or 3 elements, and X: <2 elements presented	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
(3) Description of gestational weight gain Clearly described prepregnancy weight and prenatal weight. √: ≥2 elements, O: 1 element, and X: 0 element details described	√	O	√	√	√	O	O	X	√	√	O	√	O	√	√	√	√	√	X	O	X	√
(4) Description of child body weight Clearly defined child body weight outcome and described definition for overweight/obesity. √: ≥2 elements presented, O: moderately or very clear definition of weight gain, and X: poor definition of child body weight outcome	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
(5) Soundness of information on GWG. Quality of source of information on GWG √: objective measures, O: self-report with validation, and X: Self-report	X	X	X	X	X	X	√	X	√	O	X	X	X	√	X	X	X	X	X	X	X	O
(6) Soundness of information Quality of source of information on child body weight outcome. √: objective measures, O: parental-reported, and X: self-report	√	√	X	X	√	√	X	√	√	O	√	O	√	√	√	√	√	√	√	√	O	√
(7) Description on reduction of the final sample Adequate reporting on loss to follow-up and the number of participants at each stage of study. √: both elements, O: 1 element, and X: 0 elements details described	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
(8) Analysis comparability Adequately accounted for withdrawals, lost to follow-up, and missing data in the analysis, appropriate statistical methods were used for main analysis and adjustment of potential confounders. √: all elements clearly presented, O: some presented, and X: neither element present	√	√	√	√	√	O	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
(9) Interpretation of results Results interpreted appropriately based on study design and statistics, clinically useful, appropriate presentation, present in the context of prior research, and conclusion supported by results. √: all elements clearly present, O: any other score, and X: conclusion not supported by results	√	√	√	√	√	O	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

TABLE 2: Continued.

	Li et al. [38]	Oken, et al. 2007 [25]	Gillman et al. [35]	Oken, et al. 2008 [41]	Wrotniak et al. [47]	Oken, et al. 2009 [40]	Olson et al. [42, 50]	Steube et al. [46]	Fraser et al. [23]	Magerison Zilko et al. [31]	Schack-Nielsen et al. [44]	Andersen et al. [32]	Branum et al. [33]	Lawlor et al. [37]	Rooney et al. [43]	Ensenauer et al. [34]	Hinkle et al. [36]	Laitinen et al. [24]	Lindberg et al. [49]	Magerison-Zilko et al. [39]	Stamens-Køpp et al. [45]	Ehrenthal et al. [48]
Overall quality (i) High (H): ≥ 6 good rating (√) AND zero poor rating (X) (ii) Medium (M): <6 good ratings (√) OR ≥6 good ratings (√) and ≤2 poor ratings (X) (iii) Low (L): ≥3 poor ratings (X) OR any other score	M	M	M	M	M	M	M	M	**H**	M	M	M	M	**H**	M	M	M	M	M	M	M	**H**

Notes: √ = good; O = fair; and X = poor.

Table 3: Summary of the association between maternal GWG and offspring body weight outcomes.

Study	Child age	Child BMI z-score Beta coefficient	Child OW/OB status ARR or AOR
Total GWG[#]			
Oken et al. 2007 [25]	3	0.06 (0.05, 0.07)	OW: 1.23 (1.16, 1.30)
Branum et al. 2011 [33]	4	Within-family: −0.03 (−0.08, 0.02) Between-family: 0.01 (−0.02, 0.04)	
Ensenauer et al. 2013 [34]	5.8		OW: 1.04 (1.02, 1.05)
Magerison-Zilko et al. 2012 [39]	5	0.02 (0.01, 0.03)	OW: 1.04 (1.02, 1.07)
Andersen et al. 2011 [32][a]	7	0.04 (0.03, 0.06)	
Wrotniak et al. 2008 [47]	7		OW: 1.03 (1.01, 1.05)
Schack-Nielsen et al. 2010 [44]	1–14	0.01 to 0.03 (NA)	
Oken et al. 2008 [41]	9–14	0.006 (0.005, 0.007)	OW: 1.05 (1.04, 1.05) OB: 1.08 (1.07, 1.08)
Net GWG			
Olson et al. 2009 [42, 50]	3		OW: 1.001 (NS) OB: 1.010 (NS)
Oken et al. 2007 [25]	3	0.02 (0.01, 0.03)	
Ehrenthal et al. 2013 [48]	4	0.012 (0.006, 0.017)	
Rate of GWG			
Magerison-Zilko et al. 2012 [39][b]	5		OW: Early: 1.05 (1.02, 1.09) Mid: 1.03 (0.98, 1.08) Late: 1.03 (0.98, 1.08)
Andersen et al. 2011 [32][c]	7	Early: 0.05 (0.03, 0.07) Mid: 0.06 (0.04, 0.08) Late: 0.016 (−0.002, 0.03)	
Fraser et al. 2010 [23][d,e]	9	Early/low rate: 0.17 (−0.20, 0.53) Early/medium rate: 0.33 (0.11, 0.55) Early/high rate: 0.62 (0.24, 1.01) Mid/low rate: −0.54 (2.06, 0.99) Mid/medium rate: 0.39 (−0.07, 0.84) Mid/high rate: 0.62 (0.26, 0.99) Late/low rate: 0.091 (−0.35, 0.53) Late/medium rate: −0.031 (−0.48, 0.42) Late/high rate: 0.17 (−0.13, 0.46)	OW: Early/low rate: 1.06 (0.77, 1.47) Early/medium rate: 1.14 (0.92, 1.42) Early/high rate: 1.57 (1.13, 2.18) Mid/low rate: 1.05 (0.28, 4.00) Mid/medium rate: 0.98 (0.62, 1.54) Mid/high rate: 2.00 (1.43, 2.79) Late/low rate: 0.88 (0.57, 1.36) Late/medium rate: 1.02 (0.64, 1.61) Late/high rate: 1.06 (0.81, 1.39)
Excessive GWG[¶]			
Branum et al. 2011 [33]	4	Within-family: 0.01 (−0.13, 0.14) Between-family: 0.01 (−0.08, 0.10)	
Ehrenthal et al. 2013 [48]	4	0.051 (−0.039, 0.140)	
Ensenauer et al. 2013 [34]	5.8		OW: 1.57 (1.30, 1.91)
Wrotniak et al. 2008 [47]	7		OW: 1.40 (1.00, 1.95)
Fraser et al. 2010 [23]	9	0.64 (0.55, 0.94)	
Magerison Zilko et al. 2010 [31]	2–20		OW: 1.27 (1.10, 1.48)
Oken et al. 2008 [41]	9–14	0.14 (0.09, 0.18)	OW: 1.27 (1.12, 1.44) OB: 1.42 (1.19, 1.70)
Rooney et al. 2011 [43]	9–14		OB: 1.73 (1.06, 2.80)
Inadequate GWG			
Branum et al. 2011 [33]	4	Within-family: 0.08 (0.00, 0.16) Between-family: 0.04 (−0.02, 0.10)	
Ehrenthal et al. 2013 [48]	4	−0.190 (−0.319, −0.062)	
Ensenauer et al. 2013 [34]	5.8		OW: 1.20 (0.91, 1.57)

Table 3: Continued.

Study	Child age	Child BMI z-score Beta coefficient	Child OW/OB status ARR or AOR
Wrotniak et al. 2008 [47]	7		OW: 0.93 (0.72, 1.21)
Fraser et al. 2010 [23]	9	−0.21 (−0.40, −0.03)	
Magerison Zilko et al. 2010 [31]	2–20		OW: 0.90 (NS)
Oken et al. 2008 [41]	9–14	−0.06 (−0.10, −0.01)	OW: 0.97 (1.19, 1.70) OB: 0.91 (0.74, 1.13)
Rooney et al. 2011 [43]	9–14		OB: 0.77 (0.45, 1.34)

[a]log transformed value.

[b]Rate of GWG expressed as change in kilograms per trimester. Early: 1st trimester, mid: 2nd trimester, and late: 3rd trimester.

[c]Rate of GWG expressed as change in grams per week. Early: until interview 1 (12–20 weeks of gestation), mid: between interview 1 and interview 2 (25–32 weeks of gestation), and late: between interview 2 and delivery.

[d]Rate of GWG expressed as change in grams per week. Early: 0–14 weeks of gestation, mid: >14–35 weeks of gestation, and late: >36 weeks of gestation; low rate: ≤0 g in 0–14 weeks of gestation, ≤250 g per week in other GWG periods, medium rate: 0–500 g in 0–14 weeks of gestation, 250–500 g in other GWG periods, and high rate: >500 g for all GWG period.

[e]BMI (kg/m^2) was used as the outcome.

[#]Only studies that used total GWG as continuous variables and presented full sample analyses are included.

[¶]Only studies that used adequate GWG as the referent group are included.

ARR = adjusted relative risk, AOR = adjusted odd ratio, GWG = gestational weight gain, NA = not available, NS = not significant, OW = overweight, and OB = obesity.

offspring body weight outcomes, three of which achieved statistical significance [25, 37, 48]. Increments in net GWG were associated with 0.01 to 0.07 unit increase in children's BMI z-score (Table 3).

The effect of maternal prepregnancy BMI on the association between net GWG and offspring's body weight outcomes was examined in one study. Lawlor et al. [37] found that, in the between-family model (participants from different families), the positive association between net GWG and offspring BMI at 18 years of age was stronger in normal-weight mothers than overweight mothers. In the within-family model (siblings from the same family), the positive association was retained in overweight mothers but not in normal-weight mothers (Table 4).

3.4.4. Rate of GWG and Offspring's Body Weight Outcomes. Four studies [23, 32, 39, 40] investigated the association between rate of GWG and offspring's body weight outcomes. Although the calculation of rate of GWG varied among studies, these studies consistently demonstrated that high rate of GWG in early- and mid-pregnancy was associated with increased BMI z-score and elevated risk of overweight risk among offspring, while a null association was observed between rate of GWG at late pregnancy and child's body weight outcomes (Tables 3 and 4).

3.4.5. IOM Recommended GWG and Offspring's Body Weight Outcomes. The evidence for an association between excessive GWG and offspring body weight outcomes was less than and not as consistent as total GWG. Eight studies [23, 31, 33, 34, 41, 43, 47, 48] compared the effects of excessive GWG versus adequate GWG on child's body weight outcomes, six of which achieved statistical significance [23, 31, 34, 41, 43, 47]. Offspring born to mothers who gained excessive weight during pregnancy had increased BMI z-scores (0.14 to 0.64 units) and elevated risks of overweight or obesity (27% to 73%) compared to offspring whose mothers gained adequate weight (Table 3).

Three studies [25, 35, 49] compared the effects of excessive GWG on offspring's risk of overweight with a different referent group. Lindberg and colleagues [49] compared the effects of excessive GWG and nonexcessive GWG (adequate GWG plus inadequate GWG) on offspring's risk of overweight between 5 and 8 years of age. The child's risk of overweight was 73% higher in children exposed to excessive GWG than those who did not. Two studies used data from Project Viva. Gillman et al. [35] compared the effects of excessive GWG versus nonexcessive GWG on offspring's risk of overweight and found a null association. Oken et al. [25] found that children exposed to excessive GWG had higher BMI z-score (0.47 units) and elevated risk of overweight (4-fold) than children exposed to inadequate GWG.

Eight studies [23, 31, 33, 34, 41, 43, 47, 48] showed mixed findings while examining the association between inadequate GWG and offspring body weight outcomes. Five studies [31, 33, 34, 43, 47] found a null association; three studies [23, 41, 48] found a negative association (0.06 to 0.21 units reductions in child's BMI z-score) (Table 3). Two studies [34, 47] conducted stratified analyses and found that the effects of excessive GWG on offspring's body weight outcome did not vary by maternal prepregnancy BMI (Table 4).

3.4.6. Other GWG Measures and Offspring's Body Weight Outcomes. Laitinen et al. [24] found that an additional kilogram increase in total GWG during the first 20 weeks of pregnancy increased offspring's odds of developing overweight by 3%. Stamnes Køpp and colleagues [45] showed that total GWG

Table 4: Summary of the association between maternal GWG and offspring's body weight outcomes stratified by maternal prepregnancy BMI.

Study	Child age	Child BMI z-score, B coefficient (95% CI)				Child OW/OB status, AOR/ARR (95% CI)			
		UW	NW	OW	OB	UW	NW	OW	OB
Total GWG									
Oken et al. 2007 [25]	3		0.02 (0.02, 0.06)	0.03 (0.02, 0.04)					
Hinkle et al. 2012 [36]	5	−0.06 (−0.16, 0.03)	0.02 (0.00, 0.04)	0.02 (−0.01, 0.06)	0.00 (−0.04, 0.03)				
Ensenauer et al. 2013 [34]	5.8					1.03 (0.90, 1.16)	1.04 (1.02, 1.07)	1.01 (0.98, 1.04)	1.04 (1.01, 1.07)
Wrotniak et al. 2008 [47]	7						1.07 (0.99, 1.15)	1.01 (0.99, 1.03)	
Magerison Zilko et al. 2010 [31]	2–20					1.02 (0.99, 1.05)	1.03 (1.02, 1.04)	1.02 (1.00, 1.04)	1.02 (1.00, 1.04)
Net GWG									
Lawlor et al. 2011 [37][a]	18		Within-family: 0.01 (−0.02, 0.02) Between-family: 0.07 (0.06, 0.07)	Within-family: 0.06 (0.01, 0.02) Between-family: 0.02 (0.01, 0.03)					
Rate of GWG									
Oken et al. 2009 [40][b]	3						1.16 (0.88, 1.51)	1.35 (1.01, 1.81)	1.22 (0.96, 1.56)
Excessive GWG									
Ensenauer et al. 2013 [34]	5.8					1.50 (0.36, 6.39)	1.29 (1.01, 1.66)	1.64 (1.06, 2.63)	1.17 (0.70, 2.01)
Wrotniak et al. 2008 [47]	7						3.26 (0.95, 11.16)	1.48 (1.05, 2.08)	
Inadequate GWG									
Ensenauer et al. 2013 [34]	5.8					1.74 (0.30, 8.97)	1.02 (0.71, 1.43)	2.52 (1.28, 4.91)	0.63 (0.30, 1.30)
Wrotniak et al. 2008 [47]	7						0.55 (0.22, 1.21)	0.95 (0.73, 1.24)	

[a]BMI (kg/m^2) was used as the outcome.
[b]Rate of GWG expressed as change per 0.1 kg per week.
GWG = gestational weight gain, UW = underweight, NW = normal weight, OW = overweight, OB = obesity, 95%, and CI = 95% confidence interval.

at 30 weeks of gestation was associated with 0.02 unit increments in offspring's BMI at age 3.

4. Discussion

This systematic review presents a summary of existing evidence on the associations of maternal weight gain during pregnancy with offspring body weight outcomes between 2 and 18.9 years from observational cohort studies. Overall, 23 studies met our inclusion criteria. Consistent with previous reviews [21, 22], we also found that higher total GWG significantly increased BMI z-score (0.006 to 0.06 units) and increased risk of overweight or obesity (1% to 23%). Compared to offspring whose mothers gained adequate weight during pregnancy, children of mothers who gained excessive weight had significantly higher BMI z-score (0.74 to 1.73 units) and elevated risk of overweight or obesity (1% to 57%).

A new finding in the present review is the potential impact of rate of GWG on offspring's body weight outcomes. Although an insufficient number of studies ($n = 4$) are available to draw a conclusion, they consistently demonstrated that high rates of GWG in early- and mid-pregnancy had strong adverse effects on offspring body weight outcomes. The underlying mechanisms regarding this association remain to be defined. Andersen and colleagues [32] performed path analyses and confirmed a direct pathway from rates of GWG in the early- and mid-pregnancy to offspring's body weight outcomes. We speculate that high rates of GWG in early- and mid-pregnancy increased maternal fat deposition and may have altered intrauterine environment for the development of fetal adipose tissues. Theoretically, maternal GWG can affect fetal adiposity accumulation in two possible pathways. The first one is direct transfusion of free fatty acids from the mother to fetus [52]. For underweight and normal weight women (prepregnancy BMI < 25 kg/m^2), GWG in the early- and mid-pregnancy is disproportionately fat [53]. The fat mainly deposits in mother's hips, back, and upper thighs as a caloric reserve for late pregnancy and lactation [53]. Meanwhile, mid-pregnancy is recognized as a critical period when fetal fat tissue begins to grow [54, 55]. High rates of GWG in early- and mid-gestational periods could lead to excessive maternal fat deposition that may increase the transmission of free fatty acid from mother to fetus. The second pathway is the synthesis of free fatty acids from substrates such as glucose provided by the mother [52]. Excessive fat deposition during early pregnancy could reduce maternal insulin sensitivity and glucose tolerance [56, 57] to a greater extent than the normal metabolic sequelae of pregnancy. This loss of metabolic control could translate into elevated maternal glucose concentration (i.e., glycemic excursions) which exposes the fetus to an increased glucose supply [56, 57]. Both increased transfusion of lipid and increased supply of glucose from the mother may alter the development of fat cells in fetus, thus resulting in a permanent increase in fetus's capacity to form new cells in adipose depots in postnatal life [54, 58]. However, intensive studies are needed to test these speculations.

The current findings should be interpreted with caution due to several methodological concerns. One notable methodological concern is the failure to adjust for shared familial characteristics. In this review, only two studies employed a between- and within-family design to control for shared familial characteristics. Branum et al. [33] found that the significant association between total GWG and child's BMI z-score became nonsignificant after adjusting for the shared familial characteristics. These results indicated that the positive association between maternal total GWG and offspring's BMI z-score may be entirely due to shared genetics and environmental (e.g., family lifestyle) factors rather than the intrauterine environment. Lawlor et al. [37] found that the significant association disappeared in normal-weight mother but it remained significant in overweight mothers. These findings implied that, in normal-weight mother, the association between net GWG and offspring BMI is largely due to shared familial risk factors, whereas the association in the children of overweight and/or obese mothers is driven by the exposure to both familial characteristics and intrauterine environment. A recently published study [59] examined the independent effects of GWG on offspring body weight outcomes at 11.9 years of age in 42,133 women and their 91,045 offspring, using a within-family design to minimize confounding effects of shared familial characteristics. The results showed that total GWG significantly increased offspring's BMI z-score by 0.022 units and elevated their risk of overweight by 0.7% at 11 years of age. When classifying total GWG into categories (<6 kg, ≥12 to ≤18, and >18) variable, offspring BMI increased by 0.43 units and the risk of overweight or obesity increased by 8% when comparing children born to mothers who gained >18 kg during pregnancy to those whose mothers gained <6 kg. These associations were independent of child birth weight and other covariates (e.g., gestational age, maternal smoking, parity, child age, child BMI measured at earlier ages, etc.). These findings confirmed that, after adjusting for familial characteristics, overnutrition in pregnancy could program the fetus for an increased lifetime risk for overweight or obesity, though the magnitude of this effect may be small. Additionally, these studies also demonstrated that introducing shared familiar characteristics into the analyses significantly attenuated the magnitude of associations between GWG and offspring's body weight outcomes. Thus, this important confounding variable needs to be measured and adjusted in future studies.

Shared familial characteristics consist of both genetics and/or environmental factors such as lifestyle. Since none of the studies in our review has adjusted genetic factors as covariates, we are not able to examine its modifying effects on the association of interest. Lifestyle factors such as offspring's physical activity are consistently shown to be a significant predictor of the development of childhood obesity [60]. Besides, there is a strong correlation between maternal lifestyle and offspring behaviors [61, 62]. Recent research has suggested that maternal lifestyles have dramatically changed over the last half century. Maternal activity has decreased significantly over the past 50 years, with a concomitant increase in sedentary behaviors [63, 64]. Additionally, maternal self-reported dietary consumption of away-from-home foods (e.g., packaged and convenience foods like frozen pizza) [65], numbers of eating occasions, and portion sizes per eating occasion have increased significantly over the last 30 years [66]. These changes may have significant effects on childhood lifestyle behaviors such as physical activity, dietary behaviors, and consequent obesity. In the current study, only four studies [25, 34, 36, 41] controlled for child's lifestyle factors (i.e., subjectively measured physical activity and consumptions of unhealthy foods) in the analyses, and these studies found that these factors did not alter the association between GWG and child's body weight outcomes. However, the null association could be due to the attenuation induced via poor measurement (e.g., self-report measures tend to overestimate physical activity and underestimate intake of unhealthy food in children). More research is needed to verify which shared familial characteristics are influential to the association between maternal GWG and offspring body weight outcomes.

Additionally, none of the included studies has reported whether the study is powered to detect expected difference on the primary outcome and interactive effects by maternal prepregnancy BMI. By focusing exclusively or predominantly on Caucasian women, well-educated women, and nonobese women, the extant literature is not generalizable to high risk population such as African Americans, lower income, and overweight and obese women who are more likely to exceed weight gain recommendations during pregnancy than their counterparts [16, 67–69].

Strengths and Limitations. Compared to recently published meta-analyses [21, 22], our review has several strengths such as its focus on cohort studies and careful methodological examination of published studies in terms of quality and timing of GWG measurements, adjustment of confounding variables, statistical analyses, and associated interpretations. As with any study, this review has limitations. Publication bias may be presented as the current review only included English language and published peer-reviewed journal articles. The heterogeneity in the study samples, exposures, and outcome measures included in this review limited the interpretation of the evidence and prevented the use of meta-analytical methods. The semiquantitative reporting in this review provides only an arbitrary classification of the associations and focuses more on the direction of association rather than magnitude. Several studies have drawn data from the same cohort studies, for example, the Project Viva or National Collaborative Perinatal Project, which may introduce the issue of overrepresentation and bias into the analysis sample.

5. Conclusions

The current findings suggest that GWG is a potential risk factor to prevent childhood obesity. Additionally, GWG appears to be more strongly associated with offspring's body weight outcomes during early- and mid-pregnancy than late-pregnancy, and future studies are encouraged to examine the critical timing in which GWG had the strongest impact on child's body weight outcomes. Future research should also consider the following issues: adjusting confounding effects of shared familial characteristics, improving quality of the measurement on maternal prepregnancy weight, examining the underlying mechanism or pathways, and quantifying the impact among high risk population such as African American, obese, and low income women.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Associations between Aspects of Friendship Networks, Physical Activity, and Sedentary Behaviour among Adolescents

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Background. Adolescent friendships have been linked to physical activity levels; however, network characteristics have not been broadly examined. *Method.* In a cross-sectional analysis of 1061 adolescents (11–15 years), achieving 60 minutes/day of moderate-to-vigorous physical activity (MVPA) and participating in over 2 hours/day of sedentary behaviour were determined based on friendship network characteristics (density; proportion of active/sedentary friends; betweenness centrality; popularity; clique membership) and perceived social support. *Results.* Adolescents with no friendship nominations participated in less MVPA. For boys and girls, a ten percent point increase in active friends was positively associated with achievement of 60 minutes/day of MVPA (OR 1.11; 95% CI 1.02–1.21, OR 1.14; 95% CI 1.02–1.27, resp.). For boys, higher social support from friends was negatively associated with achieving 60 minutes/day of MVPA (OR 0.63; 95% CI 0.42–0.96). Compared with low density networks, boys in higher density networks were more likely to participate in over 2 hours/day of sedentary behaviour (OR 2.93; 95% CI 1.32–6.49). Social support from friends also modified associations between network characteristics and MVPA and sedentary behaviour. *Conclusion.* Different network characteristics appeared to have different consequences. The proportion of active close friends was associated with MVPA, while network density was associated with sedentary behaviour. This poses challenges for intervention design.

1. Introduction

Low levels of physical activity and high amounts of sedentary behaviour are two significant correlates of child and adolescent overweight and obesity [1]. Paediatric obesity is associated with cardiovascular risk factors such as high blood pressure, dyslipidemia, and insulin resistance [2]. On the other hand, regular participation in physical activity can improve bone mineral density, cardiorespiratory fitness, and body composition and reduce the risk of depression [3–6]. To accrue optimal health benefits, current Canadian physical activity guidelines recommend that adolescents accumulate at least 60 minutes of moderate-to-vigorous intensity physical activity (MVPA) every day [4] and limit their recreational screen time (i.e., sedentary behaviour) to 2 hours per day or less [3]. The guidelines also recommend that adolescents limit the amount of time they spend sitting for long periods and undertaking passive transportation [3]. Despite both adolescents and parents being aware of the potential health benefits [7], only 4% of girls and 9% of boys in Canada accumulate 60 minutes of MVPA on at least six days a week [8], and 60% of youth spend more than 2 hours per day participating in screen-based activities [9]. Thus, identifying modifiable determinants of physical activity and sedentary behaviour among adolescents is important for designing effective interventions.

Social contacts and personal relationships are important determinants of adolescent health and health behaviour, including physical activity [10–12]. Adolescents' immediate social environment includes, among other factors, relationships with parents, neighbours, friends, peers, teachers, and coaches [13]. These relationships can assist in the transfer, encouragement, and discouragement of adolescent attitudes and behaviour as well as contribute to adolescents' social and emotional wellbeing. Friends have a particular influence on adolescent health as a large portion of time is spent at school and participating in extracurricular activities. Mechanisms by which friends can influence individual behaviour include coparticipation (i.e., participating in the same behaviour with a friend), modeling (i.e., witnessing a friend or peer performing a behaviour), and social norms (i.e., perception of the amount the behaviour is performed by others or perception of approval of a behaviour) [14–16]. Qualitative evidence indicates that friends provide support for physical activity initiation via coparticipation, being an active model, and verbal support [17].

Recent studies have begun to use social network analysis to gain insight into the complex world of adolescent networks of friends and peers and their influence on adolescent physical activity [10, 11]. Social network analysis is both a theoretical paradigm and methodological tool that provides a means of quantifying relationships among entities, such as individuals or organizations, and estimating patterns of association [18]. Friendship nominations amongst a group of individuals can be aggregated to form quantitative estimates of an individual's friendship network. Analysis of friendship networks has been used to examine and explain adolescent health behaviour such as smoking [19], body mass index, and dietary behaviour [20], and more recently physical activity and sedentary behaviour [10, 11]. There is evidence to suggest associations between popularity, friend behaviour, and friendship reciprocity with regard to an individual's physical activity level; however, there are still mixed results on the association between aspects of friendship networks and sedentary behaviour [10, 11]. Gender differences also exist with regard to the influence of social networks on physical activity. For instance, friends' physical activity has been associated with boys', but not girls', physical activity [21–23].

Within social network analysis there are a variety of measures that examine individual positioning and relationships which have yet to be explored within the context of physical activity and sedentary behaviour but that have been examined in relation to other behaviours [24, 25]. These measures include ego-level variables such as clique membership (i.e., a group of at least three individuals who are all connected), betweenness centrality (i.e., an individual's tendency to link other network members), as well as network-level variables such as network density (i.e., number of connections in a network as a percentage of the total possible connections) [18]. These network measures could provide an additional layer of understanding and greater insight into the overall influence of friends on individual behaviour. Network density has been examined in the adolescent substance abuse literature [24, 25], and its applicability to physical activity and sedentary behaviour is worth investigating. While the associations between popularity and physical activity and sedentary behaviour have been examined [26–30], there has been less focus on those adolescents who receive no friendship nominations. Having fewer or no friends may result in limited opportunities for coparticipation in physical activity.

The aim of this study was twofold: (1) to examine the associations between aspects of school-based friendship networks (i.e., friendship network density, friend behaviour, popularity, and network roles), general perceived social support from friends, and achievement of recommended levels of physical activity and sedentary behaviour for adolescent boys and girls and (2) to examine the extent to which general perceived social support from friends modifies associations between friendship network measures and physical activity and sedentary behaviour.

2. Material and Methods

2.1. Data Source. This study is part of a larger Calgary-based (Alberta, Canada) project entitled Creating Opportunities for Resilience and Engagement (CORE) Connections. Six Catholic schools in Calgary were invited to participate in this study. The sample constituted all grades from 5 to 9 schools in the school district who had over 600 students in size and who did not offer specialized programming (e.g., performing arts, hockey). Seven schools were approached to take part and one refused. The schools were situated in different neighbourhoods within the metropolitan area. The median income of neighbourhoods in which the schools were situated ranged from \$72,170 (School C) to \$92,453 (School D) [31]—higher than the median income for all Calgary neighbourhoods (\$67,238) [31]. In each school, all adolescents in grades from 7 to 9 were invited to participate in this study. A study information package was sent to homes seeking parental consent for their adolescent's participation. Two surveys were administered in school in November and December 2010. One survey captured physical activity, sedentary behaviour, general perceived social support from friends, and sociodemographic characteristics. The second survey captured adolescents' within-grade friendship network. Students completed online surveys on banks of computers sitting at least one meter apart. Research assistants explained the importance of privacy and confidentiality and monitored the room constantly, making sure that students were not looking at each other's screens.

2.2. Study Variables

2.2.1. Physical Activity. Two survey items captured the number of days adolescents achieved at least 60 minutes of MVPA, outside of school hours, during (1) the past 7 days and (2) in a usual week [32]. The composite score, estimated from averaging responses to these two items, has acceptable test-retest reliability [32]. To reflect the current Canadian youth physical activity recommendations [4], we dichotomized the composite score into (1) achieving at least 60 minutes of MVPA on six or fewer days per week (*insufficiently active*) versus (2) achieving at least 60 minutes of MVPA on 7 days per week (*sufficiently active*).

2.2.2. Sedentary Behaviour. Two survey items captured the time adolescents spend watching television or videos, using a computer, playing video games, or using a handheld device, outside of school, on a typical (1) weekday and (2) weekend day [33]. The average hours spent sedentary per day was estimated ([5 × weekday hours + 2 × weekend hours]/7 days per week) and dichotomized into (1) more than 2 hours per day (*high sedentary*) versus (2) 2 hours or less per day (*low sedentary*), reflecting the current Canadian adolescent sedentary behaviour guidelines [3]. Acceptable test-retest reliability for weekday and weekend television/video use (r = 0.80 and 0.69, resp.,) and weekday and weekend computer use (r = 0.66 and 0.71, resp.,) has been reported [33].

2.2.3. General Perceived Social Support from Friends. General perceived social support from friends was measured through a social support scale consisting of four items. These items asked adolescents to report on how often (never, sometimes, most of the time, or all the time) they had friends who tried to help them; they could count on when things go wrong; they could share happy and sad times; and they could talk to about problems [34]. Responses to the four items were averaged, with higher scores reflecting higher levels of support. Internal consistency for this scale was acceptable (Cronbach's $\alpha = 0.82$).

2.2.4. Sociodemographic Characteristics. Socioeconomic status was measured using the family affluence scale (FAS) [35] which included four items asking adolescents to report the number of cars, vans, or trucks their family owned (i.e., 0, 1, or ≥2 vehicles); if they had their own bedroom (i.e., no = 0 or yes = 1); the number of times their family travelled away on holiday (i.e., 0, 1, 2, or ≥2 times in past 12 months); and the number of computers/laptops their family owned (i.e., 0, 1, 2, or ≥2). The responses to FAS items were summed and tertiled into low (FAS: <6), medium (FAS: 6-7), and high family affluence (FAS: ≥8). The FAS reflects household material wealth and it has been used in several studies investigating associations between family affluence, physical activity, and sedentary behaviour [36, 37], as well as in the Health Behaviour in School-Aged Children WHO Collaborative Cross-National Study [35]. Adolescents reported their gender, age (i.e., ≤12 years, 13 years, and ≥14 years old), how long they have lived in Canada (i.e., ≤5 years or >5 years), and residential relocation (i.e., did not move or moved at least once in the last 12 months). The school attended by the adolescent was also recorded (i.e., school A to F). The school attended may provide a proxy for community situatedness and affluence that was not captured in the surveys but could be important with regard to physical activity and sedentary behaviour.

2.2.5. Social Network Variables. Adolescents were presented with a list of all individuals enrolled in their grade and were asked to indicate their closest friends. In other words, we used complete network survey methods, as opposed to ego-network methods, which ask respondents to name a certain number of friends and investigate the relationships among only those nominated. Using social network analysis software UCINET [38], seven ego-network variables were estimated based on the received ("incoming") friendship nominations from close friends. The variables included (1) ego friendship network density (density); (2) proportion of received nominations from adolescents who achieved recommended levels of physical activity (proportion of active close friends); (3) proportion of received nominations from adolescents who participated in more than the recommended amount of sedentary behaviour (proportion of sedentary close friends); (4) amount of times an individual lies on the shortest path between two other individuals (betweenness centrality); (5) total number of nominations an adolescent received from other adolescents (popularity); (6) whether an adolescent has connections with at least two other adolescents and all three adolescents are connected through friendship nominations (clique member); and (7) if the adolescent received no friendship nominations. All variables were normalized using the number of adolescents in each grade. Density was dichotomized at the median density (12%) of the 18 networks (3 grades × 6 schools). Higher density reflects a higher connectivity between individuals within each grade. Clique member was dichotomized (i.e., not a member or member). All other social network variables were analyzed as numerical or continuous. The variables that were chosen—density, proportion of active close friends, proportion of sedentary close friends, popularity, clique member, and popularity—were consistent with theories of contagion in networks, theories of homophily (like people hanging out with like people), and balance theory (ties among triads), consistent with our interest in the generation and maintenance of norms, albeit that these were cross-sectional investigations [39]. We included betweenness centrality as it is a measure of social status and potential influence, due to the capacity to control flows of information [24]. It is only possible to measure in complete network surveys.

2.3. Statistical Analysis. Gender-stratified descriptive statistics including mean and standard deviations (SD) for numerical variables (i.e., general perceived social support from friends, proportion of active close friends, proportion of sedentary close friends, betweenness centrality, and popularity) and frequencies for categorical variables (i.e., age, FAS, school, time living in Canada, and residential relocation in the last 12 months, friendship network density, clique member, receiving no friendship nominations) were estimated. Gender-stratified independent samples t-tests, Pearson's chi-square tests, and subsequent z-tests for pairwise comparisons of proportions were undertaken to compare differences in all numerical and categorical variables, respectively.

Adjusted binary logistic regression models estimated the odds ratios (OR) and 95% confidence intervals (95% CI) for the association between sociodemographic variables (age, FAS, school attended, time living in Canada, and residential relocation), social network variables (friendship network density, proportion of active close friends, proportion of sedentary close friends, betweenness centrality, popularity, and clique member), and general perceived support from friends, and the likelihood of being (1) sufficiently active versus insufficiently active and (2) high sedentary versus low sedentary. Taking an exploratory approach, we also conducted a backward stepwise likelihood ratio test to identify significant interaction terms ($P < 0.05$) between general perceived social support from friends and each of the social network variables.

To aid in interpretation of the regression results, the proportion of active close friends and proportion of sedentary close friends were converted to percentages and rescaled so that a one-unit change was equal to a ten percentual point change in these variables. Adolescents who did not receive a friendship nomination were excluded from the regression models because at least one nomination was required for the calculation of the proportion of active close friends and proportion of sedentary close friends. Instead, Mann-Whitney U Tests were used to compare the amount of weekly physical activity and daily sedentary behaviour undertaken between those who did not receive a friendship nomination and those who received at least one friendship nomination. All analysis was conducted using SPSS version 20 [40].

3. Results and Discussion

From the six schools, all adolescents ($n = 1,393$) in grades 7 through 9 were invited to participate, of which 1,122 provided active consent (80.5%). A total of 1,061 adolescents subsequently provided complete data and were included in the analysis (76.2% of all those eligible).

3.1. Descriptive Statistics. The sample included 535 girls (50.4%) and 526 boys (49.6%), excluding adolescents who did not receive any close friendship nominations (Tables 1 and 2). Adolescents' age ranged from 11 to 15 years and was distributed as follows: 12 years and younger (boys = 40.9%, girls = 40.0%), 13 years (boys = 31.0%, girls = 33.3%), and 14 years and older (boys = 28.1%, girls = 26.7%). Similar percentages of boys and girls had high family affluence (boys = 37.5%, girls = 38.7%), middle family affluence (boys = 43.0%, girls = 44.5%), and low family affluence (boys = 19.6%, girls = 16.8%). A higher percentage of boys achieved recommended levels of physical activity per week compared with girls (boys = 16.0% and girls = 7.3%), while participation in at least two hours of sedentary activity per day was similar between boys and girls (boys = 79.8% and girls = 78.7%).

The mean number of incoming closest friend nominations for boys was 6.99 (SD = 3.79) and for girls was 6.52 (SD = 3.45). Network densities for close friendships across the schools and grades ranged from 7.0% to 14.0%. There were 21 adolescents (9 boys, 12 girls) who did not receive any friendship nominations. Among these adolescents, 7 (33.3%) were ≤12 years, 8 (38.1%) were 13 years, and 6 (28.6%) were ≥14 years of age. Moreover, 7 adolescents (33.3%) had low family affluence, 8 (38.1%) had medium family affluence, and 6 (28.6%) had high family affluence.

3.2. Physical Activity and Sedentary Behaviour among Those Who Received No Incoming Friendship Nominations. Adolescents who received no incoming nominations participated in significantly ($P < 0.05$) fewer days per week of at least 60 minutes of MVPA compared with those who received at least one friendship nomination (mean = 3.28 days/wk, SD = 1.76 days/wk versus 4.33 days/wk, SD = 1.81 days/wk, resp.). No difference in hours per day of sedentary behaviour was found.

3.3. Associations between Social Network-Derived Variables and Physical Activity and Sedentary Behaviour for Boys. Adjusting for all covariates, a ten percentage point increase in active close friends was significantly associated with an increased likelihood of being sufficiently active (OR 1.11; 95% CI 1.02–1.21) (Table 3). Boys with a higher general perceived social support from friends were significantly less likely to be sufficiently active (OR 0.63; 95% CI 0.42–0.96). Boys from school E were significantly less likely to be active compared with school A (OR 0.26; 95% CI 0.08–0.84). There were no significant interactions between social network variables and boys' general perceived social support from friends in relation to physical activity.

Adjusting for all covariates, boys in high density network were more likely to be highly sedentary compared with boys in low density networks (OR 2.93; 95% CI 1.32–6.49) (Table 3). Compared with boys ≤12 years of age, boys ≥14 years of age were more likely to be highly sedentary (OR 2.23; 95% CI 1.04–4.77). Moreover, boys in schools C (OR 2.92; 95% CI 1.04–8.21) and F (OR 4.24; 95% CI 1.30–13.77) were significantly more likely to be highly sedentary compared with boys in school A. There was a significant interaction ($P < 0.05$) between both the proportion of active close friends (OR 1.12; 95% CI 1.00–1.26) and proportion of sedentary close friends (OR 1.16; 95% CI 1.01–1.32) and general perceived social support from friends and being highly sedentary.

3.4. Associations between Social Network-Derived Variables and Physical Activity and Sedentary Behaviour for Girls. After adjusting for all covariates, a ten percentage point increase in active close friends was associated with achieving sufficient levels of physical activity (OR 1.14; 95% CI 1.02–1.27) (Table 4). No other covariates were significantly associated with sufficient levels of physical activity among girls. There was a significant interaction ($P < 0.05$) between the proportion of sedentary close friends and general perceived support from friends in relation to being sufficiently active (OR 1.31; 95% CI 1.04–1.67).

Adjusting for all other covariates, girls in schools C, E, and F were more likely to be highly sedentary (OR 2.89; 95% CI 1.22–6.83, OR 2.71; 95% CI 1.03–7.13, OR 6.18; 95% CI 1.94–19.64, resp.,) compared to girls in school A (Table 4). There was a significant interaction ($P < 0.05$) between general perceived social support from friends and clique membership and a decreased likelihood of being highly sedentary (OR 0.38; 95% CI 0.15–0.96). No other significant associations were found between the other covariates and sedentary behaviour among girls.

3.5. Discussion. The low prevalence of participation in at least 60 minutes of MVPA every day and high prevalence of participation in over 2 hours per day of sedentary behaviour (i.e., recreational screen time) in our sample of adolescents

Table 1: Descriptive statistics for the sociodemographic characteristics, general perceived social support from friends, physical activity, and sedentary behaviour for boys (n = 526).

	Physical activity		Sedentary behaviour	
	Sufficiently active (≥60 min of MVPA every day)	Insufficiently active (≥60 min of MVPA on <7 days/week)	High sedentary (>2 hrs/day of sedentary behaviour)	Low sedentary (≤2 hrs/day of sedentary behaviour)
Sociodemographic characteristics				
Age [n (%)]				
12 years and younger	37 (17.2)	178 (82.8)	157 (73.0)	58 (27.0)[b]
13 years	31 (19.0)	132 (81.0)	132 (81.0)	31 (19.0)
14 years and older	16 (10.8)	132 (89.2)	132 (89.2)	16 (10.8)[b]
Family affluence [n (%)]				
Low	11 (10.7)	92 (89.3)[a]	80 (77.7)	23 (22.3)
Medium	32 (14.2)	194 (85.8)	177 (78.3)	49 (21.7)
High	41 (20.8)	156 (79.2)[a]	164 (83.2)	33 (16.8)
Length of time in Canada [n (%)]				
More than 5 years	6 (9.0)	61 (91.0)	56 (83.6)	11 (16.4)
5 years or less	78 (17.0)	381 (83.0)	365 (79.5)	94 (20.5)
Number of times moved last year [n (%)]				
Did not move	74 (17.2)	356 (82.8)	340 (79.1)	90 (20.9)
Moved at least once	10 (10.4)	86 (89.6)	81 (84.4)	15 (15.6)
Social network characteristics				
Incoming close friend nominations [n (%)]				
Received ≥1 nomination	87 (16.1)	453 (83.9)	432 (80.0)	108 (20.0)
Received no nominations	0 (0.0)	9 (100.0)	5 (55.6)	4 (44.4)
Proportion active close friends [mean (SD)]	0.40 (0.4)[c]	0.30 (0.3)[c]	0.30 (0.3)[d]	0.38 (0.3)[d]
Proportion sedentary close friends [mean (SD)]	0.67 (0.3)	0.72 (0.3)	0.72 (0.3)	0.68 (0.3)
Betweenness centrality [mean (SD)]	3.63 (4.2)	3.07 (4.2)	3.14 (4.3)	3.26 (3.9)
Popularity (incoming nominations) [mean (SD)]	7.08 (3.6)	6.98 (3.8)	6.89 (3.7)	7.40 (4.0)
Clique member [n (%)]				
Not a member	35 (18.0)	155 (82.0)	156 (82.1)	34 (17.9)
Member	49 (14.6)	287 (85.4)	265 (78.9)	71 (21.1)
Perceived support from friends [mean (SD)][f]	3.15 (0.7)	3.28 (0.6)	3.27 (0.6)	3.20 (0.6)
Total boys [n (%)]	84 (16.0)	442 (84.0)	421 (80.0)	105 (20.0)

[a,b]Significant ($P < 0.05$) chi-square and Bonferroni-adjusted pair-wise comparison (z-test); [c,d]significant ($P < 0.05$) difference in means (Mann-Whitney U-test), [f]average general perceived social support index: 1 = received support none of the time to 4 = received support all of the time in increments of 0.25, MVPA: moderate-to-vigorous intensity physical activity, SD: standard deviation.

is consistent with other Canadian studies [9, 41]. For boys and girls, a higher proportion of active close friends were associated with an increased likelihood of achieving sufficient levels of physical activity. We also found that, for boys, friendship network density was positively associated with sedentary behaviour. An important finding was that adolescents who received no friendship nominations spent significantly fewer days per week participating in 60 minutes of MVPA compared with adolescents who received at least one friendship nomination. Our study highlights the potential importance of close friendship network characteristics in influencing physical activity and sedentary behaviour in adolescents.

The association between close friends' physical activity and an individual's physical activity was consistent with previous findings [10, 11]; however, studies that undertook gender-stratified analysis found associations for friends' physical activity and physical activity among boys, but not among girls [21–23]. Similar to Sirard et al. [42] who found that friend's weekly hours of MVPA were significantly associated with boy's and girl's physical activity, we found that, regardless of gender, a higher proportion of active close friends were positively associated with achieving sufficient levels of physical activity. Having close friends who are active appears beneficial; however, our findings also suggest that not being

Table 2: Descriptive statistics for the sociodemographic characteristics, general perceived social support from friends, physical activity, and sedentary behaviour for girls ($n = 535$).

	Physical activity		Sedentary behaviour	
	Sufficiently active (≥60 min of MVPA every day)	Insufficiently active (≥60 min of MVPA on <7 days/week)	High sedentary (>2 hrs/day of sedentary behaviour)	Low sedentary (≤2 hrs/day of sedentary behaviour)
Sociodemographic characteristics				
Age [n (%)]				
12 years and younger	22 (10.3)	192 (89.7)	156 (72.9)	58 (27.1)[a]
13 years	11 (6.2)	167 (93.8)	140 (78.7)	38 (21.3)
14 years and older	6 (4.2)	137 (95.8)	122 (85.3)	21 (14.7)[a]
Family affluence [n (%)]				
Low	6 (6.7)	84 (93.3)	70 (77.8)	20 (22.2)
Medium	14 (5.9)	224 (94.1)	186 (78.2)	52 (21.8)
High	19 (9.2)	188 (90.8)	162 (78.3)	45 (21.7)
Length of time in Canada [n (%)]				
More than 5 years	3 (5.3)	54 (94.7)	43 (75.4)	14 (24.6)
5 years or less	36 (7.5)	442 (92.5)	375 (78.5)	103 (21.5)
Number of times moved last year [n (%)]				
Did not move	28 (6.6)	397 (93.4)	336 (79.1)	89 (20.9)
Moved at least once	11 (10.0)	99 (90.0)	82 (74.5)	28 (25.5)
Social network characteristics				
Incoming close friend nominations [n (%)]				
Received ≥1 nomination	39 (7.2)	503 (92.8)	425 (78.4)	117 (21.6)
Received no nominations	0 (0.0)	12 (100.0)	11 (91.7)	1 (8.3)
Proportion active close friends [mean (SD)]	0.43 (0.4)[c]	0.25 (0.4)[c]	0.24 (0.3)[d]	0.34 (0.4)[d]
Proportion sedentary close friends [mean (SD)]	0.75 (0.3)	0.74 (0.3)	0.76 (0.3)	0.70 (0.3)
Betweenness centrality [mean (SD)]	2.68 (3.0)	3.16 (4.0)	3.26 (4.0)	2.66 (3.5)
Popularity (incoming nominations) [mean (SD)]	6.36 (3.1)	6.53 (3.5)	6.67 (3.6)[e]	5.97 (2.7)[e]
Clique member [n (%)]				
Not a member	9 (6.1)	138 (93.9)	115 (78.2)	32 (21.8)
Member	30 (7.7)	358 (92.3)	303 (78.1)	85 (21.9)
Perceived support from friends [mean (SD)][f]	3.54 (0.6)	3.53 (0.5)	3.53 (0.5)	3.53 (0.5)
Total girls [n (%)]	39 (7.3)	496 (92.7)	418 (78.1)	117 (21.9)

[a,b]Significant ($P < 0.05$) chi-square and Bonferroni-adjusted pair-wise comparison (z-test); [c,d,e]significant ($P < 0.05$) difference in means (Mann-Whitney U test), [f]average general perceived social support index: 1 = received support none of the time to 4 = received support all of the time in increments of 0.25, MVPA: moderate-to-vigorous intensity physical activity, SD: standard deviation.

nominated as a close friend may have a negative impact on physical activity behaviour. While few adolescents did not receive any close friendship nominations ($n = 21$), they were found to participate in less MVPA than those who received at least one close friendship nomination. Similar results were found elsewhere regarding other health-related behaviour. For example, isolate adolescents are significantly more likely to smoke compared with adolescents who are socially connected to others (i.e., clique members) [19]. It is possible that adolescents who are not considered a close friend by others receive limited support or encouragement to participate in physical activity and may have no opportunities to coparticipate in physical activities with others. A complete network analysis, like that conducted here, allowed the investigators to observe those without friendship nominations, while an ego-network analysis, by definition, would not.

This study was able to contribute knowledge relating to network density and network positioning and physical activity and sedentary behaviour. Boys who were in a higher density network were more likely to be sedentary compared with those in a low density network. As the majority of boys were sedentary (80%), a higher density network may have allowed for more exposure to normative attitudes, ideals, and behaviour among adolescents within the network, which could result in an increased likelihood of an individual being highly sedentary. Haynie [43] found similar results for

Table 3: Odds ratios (OR) and 95% confidence intervals (95% CI) for the association between sociodemographic characteristics, social network variables, general perceived social support from friends, physical activity, and sedentary behaviour for boys (n = 526).

	Sufficiently active (≥60 min of MVPA every day)	High sedentary (>2 hrs/day of sedentary behaviour)	
	Adjusted main effects OR (95% CI)	Adjusted main effects OR (95% CI)	Adjusted main effects and interaction OR (95% CI)
Sociodemographic characteristics			
School			
A[#]	1.00	1.00	1.00
B	0.43 (0.18–1.06)	2.34 (0.95–5.74)	2.40 (0.90–6.01)
C	0.42 (0.15–1.15)	2.92 (1.04–8.21)[*]	2.94 (1.02–8.47)[*]
D	0.67 (0.22–2.06)	1.54 (0.50–4.77)	1.50 (0.48–4.74)
E	0.26 (0.08–0.84)[*]	1.95 (0.66–5.76)	1.76 (0.58–5.32)
F	0.51 (0.16–1.61)	4.24 (1.30–13.77)[*]	4.00 (1.20–13.33)[*]
Age			
12 yrs and younger[#]	1.00	1.00	1.00
13 yrs	1.40 (0.71–2.75)	1.09 (0.58–2.08)	1.16 (0.61–2.22)
14 yrs and older	0.83 (0.35–1.95)	2.23 (1.04–4.77)[*]	2.39 (1.10–5.18)[*]
Family affluence			
Low[#]	1.00	1.00	1.00
Middle	1.29 (0.60–2.77)	1.21 (0.66–2.23)	1.25 (0.68–2.31)
High	2.00 (0.94–4.27)	1.55 (0.81–2.94)	1.54 (0.80–2.94)
Length of time in Canada			
More than 5 years[#]	1.00	1.00	1.00
5 years or less	0.48 (0.19–1.25)	1.23 (0.58–2.63)	1.25 (0.58–2.70)
Number of times moved last year			
Did not move[#]	1.00	1.00	1.00
Moved at least once	0.75 (0.35–1.61)	1.10 (0.58–2.10)	1.01 (0.52–1.94)
Social network characteristics			
Density			
Low (density <12%)[#]	1.00	1.00	1.00
High (density ≥12%)	0.56 (0.23–1.33)	2.93 (1.32–6.49)[*]	2.99 (1.34–6.69)[*]
Proportion of active close friends	1.11 (1.02–1.21)[*]	0.96 (0.89–1.03)	0.66 (0.00–0.96)[*]
Proportion of sedentary close friends	1.02 (0.92–1.12)	0.91 (0.83–1.01)	0.58 (0.00–0.88)[*]
Betweenness centrality	1.02 (0.96–1.08)	1.00 (0.95–1.07)	1.01 (0.95–1.07)
Popularity	1.02 (0.97–1.07)	0.98 (0.93–1.03)	0.97 (0.93–1.02)
Clique member			
Member[#]	1.00	1.00	1.00
Not a member	1.21 (0.68–2.16)	1.32 (0.76–2.27)	1.31 (0.75–2.27)
General perceived social support from friends[a]	0.63 (0.42–0.96)[*]	1.35 (0.92–1.98)	0.34 (0.12–1.03)
Interactions			
Proportion of active close friends ∗ General perceived social support from friends			1.12 (1.00–1.26)[*]
Proportion of sedentary close friends ∗ General perceived social support from friends			1.16 (1.01–1.32)[*]

[*] $P < 0.05$, [#] referent category, [a] average general perceived social support index: 1 = received support none of the time to 4 = received support all of the time in increments of 0.25, MVPA: moderate-to-vigorous physical activity, OR: odds ratio, CI: confidence interval.
No significant interactions between friendship network characteristics and general perceived social support for boys' physical activity.

Table 4: Odds ratios (OR) and 95% confidence intervals (95% CI) for the association between sociodemographic characteristics, social network variables, general perceived social support from friends, physical activity, and sedentary behaviour for girls (n = 535).

	Sufficiently active (≥60 min of MVPA every day)		High sedentary (>2 hrs/day of sedentary behaviour)	
	Adjusted main effects OR (95% CI)	Adjusted main effects and interaction OR (95% CI)	Adjusted main effects OR (95% CI)	Adjusted main effects and interaction OR (95% CI)
Sociodemographic characteristics				
School				
A[#]	1.00	1.00	1.00	1.00
B	0.17 (0.03–1.04)	0.16 (0.03–1.00)	1.73 (0.78–3.88)	1.79 (0.80–4.03)
C	0.86 (0.24–3.15)	0.81 (0.22–2.94)	2.89 (1.22–6.83)*	3.10 (1.30–7.38)*
D	0.83 (0.16–4.24)	0.90 (0.17–4.66)	1.21 (0.46–3.18)	1.20 (0.46–3.16)
E	0.38 (0.07–2.01)	0.38 (0.07–2.07)	2.71 (1.03–7.13)*	2.85 (1.08–7.52)*
F	0.96 (0.19–4.73)	0.99 (0.20–4.89)	6.18 (1.94–19.64)*	6.87 (2.11–22.35)*
Age				
12 yrs and younger[#]	1.00	1.00	1.00	1.00
13 yrs	0.68 (0.27–1.74)	0.69 (0.27–1.79)	1.19 (0.66–2.17)	1.16 (0.64–2.12)
14 yrs and older	0.50 (0.14–1.80)	0.48 (0.13–1.77)	1.61 (0.78–3.35)	1.63 (0.78–3.41)
Family affluence				
Low[#]	1.00	1.00	1.00	1.00
Middle	0.88 (0.31–2.49)	0.79 (0.28–2.27)	1.11 (0.60–2.07)	1.09 (0.58–2.04)
High	1.46 (0.53–4.03)	1.41 (0.51–3.92)	1.15 (0.61–2.18)	1.16 (0.61–2.21)
Length of time in Canada				
More than 5 years[#]	1.00	1.00	1.00	1.00
5 years or less	0.54 (0.15–2.01)	0.61 (0.16–2.28)	0.76 (0.37–1.55)	0.76 (0.37–1.56)
Number of times moved last year				
Did not move[#]	1.00	1.00	1.00	1.00
Moved at least once	1.55 (0.70–3.42)	1.60 (0.72–3.54)	0.82 (0.48–1.40)	0.91 (0.53–1.58)
Social network characteristics				
Density				
Low (density <12%)[#]	1.00	1.00	1.00	1.00
High (density ≥12%)	1.05 (0.30–3.65)	1.07 (0.30–3.81)	1.43 (0.70–2.94)	1.48 (0.72–3.04)
Proportion of active close friends	1.14 (1.02–1.27)*	1.15 (1.03–1.28)*	0.94 (0.88–1.01)	0.94 (0.88–1.00)
Proportion of sedentary close friends	1.02 (0.88–1.19)	0.00 (0.00–0.90)*	0.96 (0.88–1.05)	0.96 (0.88–1.05)
Betweenness centrality	0.96 (0.87–1.07)	0.96 (0.86–1.06)	1.04 (0.97–1.11)	1.76 (0.96–3.22)
Popularity	0.99 (0.91–1.07)	0.98 (0.91–1.07)	1.03 (0.99–1.10)	1.03 (0.98–1.09)
Clique member				
Member[#]	1.00	1.00	1.00	1.00
Not a member	0.84 (0.34–2.04)	0.75 (0.30–1.86)	1.38 (0.80–2.41)	39.86 (1.54–1034.20)*
General perceived social support from friends[a]	1.06 (0.55–2.04)	0.14 (0.02–0.88)	0.98 (0.65–1.48)	1.88 (0.99–3.55)
Interactions				
Proportion of sedentary close friends ∗ General perceived social support from friends		1.31 (1.04–1.67)*		
Clique member ∗ General perceived social support from friends				0.38 (0.15–0.96)*

*$P < 0.05$, [#]referent category, [a]average general perceived social support index: 1 = received support none of the time to 4 = received support all of the time in increments of 0.25, MVPA: moderate-to-vigorous physical activity, OR: odds ratio, CI: confidence interval.

adolescent delinquency; the interaction between high density and delinquent peer networks resulted in higher delinquency involvement.

Although not the primary focus of our study, there were significant differences in the likelihood of adolescents being sufficiently active, as well as highly sedentary, among the six schools. This study, which is part of a larger project focused on improving health and wellbeing, was not initially designed to capture information about school policies, programs, or opportunities for physical activity and sedentary behaviour. Speculatively, it is possible that school characteristics and opportunities may have contributed to differences in physical activity and sedentary behaviour. For example, a review by Bonell et al. [44] found that schools with higher attainment and attendance, combined with lower truancy, had lower rates of student substance abuse. With regard to physical activity, Cradock et al. [45] found that characteristics of school campuses (i.e., school campus area per student, building area per student, and play area per student) were each associated with higher levels of physical activity. Therefore, it is possible that school characteristics may have accounted for the differences in levels of sufficiently active and highly sedentary adolescents among the schools in this study.

Evidence indicates that perceived social support for physical activity is positively associated with physical activity among adolescents [12, 46, 47]. Our study did not measure perceived support for physical activity but assessed the role of feeling emotionally supported by friends, which was not limited to within-school friends. We found evidence of effect modification between perceived social support and friendship network variables in relation to sedentary behaviour. Boys who reported higher general perceived social support from friends and had a higher proportion of *active* close friends were more likely to be sedentary, and boys who reported higher general perceived social support from friends and had a higher proportion of *sedentary* close friends were also more likely to be sedentary. We are unaware of previous studies examining the interaction between perceived social support from friends and social network variables in relation to physical activity and sedentary behaviour. Reasons for these counter-intuitive findings are therefore speculative. The findings could reflect patterns of social interaction among adolescents that may provide individuals with a virtual (e.g., Facebook, online gaming) versus physical form (e.g., sports teams, face-to-face games) of social support. Boys may also receive social support from friends who are both sufficiently active and highly sedentary; boys may participate in team sports with friends and also participate in sedentary activities with these friends, such as watching televised professional sports together. Future research may wish to examine the extent to which "influential" friends within social networks influence physical activity and sedentary behaviour, as well as the role of peer pressure, starting with qualitative studies.

Interactions between general perceived social support and social network variables were also found for girls. Girls who reported higher perceived general social support from friends and had a higher number of sedentary close friends were more likely to be sufficiently active. Moreover, girls who reported higher perceived social support from friends and who were members of a clique were less likely to be highly sedentary. It is possible that girls may have nonschool-based friends with whom they are active (e.g., sports teams). Our analysis did not examine the gender distribution of individuals' friendship networks. Girls may receive social support from their female friends, who also happen to be highly sedentary but also have male friends with whom they participate in physical activities. Some of our counter-intuitive findings for boys and girls may reflect our measure of general perceived social support which did not capture social support specifically associated with physical activity or sedentary behaviour. There may also be extenuating factors, such as family support, which have been shown to influence adolescent physical activity [48] and sedentary behaviour [49] that were not accounted for in this analysis.

This study has several limitations that should be considered. Causal inferences cannot be drawn from this cross-sectional study. Previous longitudinal analyses have shown that friends' physical activity tends to become similar over time [21, 27, 50–52], indicating a process of friendship influence or socialization; however, several of these studies [50–52] also found that adolescents tend to select their friends based on similarities in physical activity. The low prevalence of sufficiently active boys (16.0%) and girls (7.3%) may have limited the statistical power to detect some meaningful associations from the regression models. The mismatch in context between our physical activity and sedentary behaviour measures (i.e., behaviour both inside and outside of school) and social network measure (i.e., close friends inside the school) might have resulted in fewer significant associations being found.

4. Conclusions

The determinants of physical activity and sedentary behaviour in children and adolescents are multifaceted and complex. Individual-level behaviour (e.g., motor ability and skill) and psychological characteristics (e.g., self-efficacy, attitudes, enjoyment), the social environment (e.g., friends and parents, family relationships and structure, and culture), the physical environment (e.g., neighbourhood parks, play equipment, availability and access to screen-based devices, and urban design), policy (e.g., mandatory physical education and activity breaks in schools), and programs (e.g., walking school bus) together influence patterns of physical activity and sedentary behaviour that adolescents undertake [48]. Our study focused on the influence of the social environment only and more specifically one aspect of the social environment—adolescent school-based friendship networks—on physical activity and sedentary behaviour. Our study findings suggest that characteristics of school-based close friendship networks are differentially associated with physical activity and sedentary behaviour. Specifically, social network-derived variables associated with physical activity differ from those associated with sedentary behaviour; relationships between individuals' and the proportion of active close friends appear to be associated with physical activity, while network density appears to be associated with sedentary behaviour.

Results from this study invite consideration of future public health interventions which utilize friendship influence to increase physical activity among adolescents. While we recognize that close friendship is a matter of complex personal choice, the opportunities to get to know new and more people, which could lead to this choice, are possibly amenable. This requires further investigation and understanding. Increasing the proportion of active individuals within a friendship network, particularly those with a higher number of friends, may result in a snowball effect and increase the likelihood of other individuals becoming sufficiently active. Harnessing the benefits of positive friendship influence to promote modeling and coparticipation could help adolescents achieve the recommended levels of physical activity required for optimal health benefits. In other fields, attempts have been made to harness the properties of friendship networks to improve health behaviour [53]. However, we have a partial view of a more complicated picture. Not only can an individual be both sedentary and active [54] we have shown that different aspects of networks appear to support these behaviour differently. The low prevalence of sufficiently active and high prevalence highly sedentary adolescents in our study is worrying and therefore suggests that broader multifaceted community, environmental, and school-based interventions may be of more immediate practical benefit [55, 56].

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Clinical Study

Intervention Effects of a School-Based Health Promotion Programme on Obesity Related Behavioural Outcomes

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Studies have shown preventive effects of an active lifestyle during childhood on later life; therefore, health promotion has to start early. The programme "Join the Healthy Boat" promotes a healthy lifestyle in primary school children. In order to evaluate it, children's behaviours in respect of increased physical activity (PA), a decrease in screen media use (SMU), more regular breakfast, and a reduction of the consumption of soft drinks (SDC) were investigated. 1943 children (7.1 ± 0.6 years) participated in the cluster-randomised study and were assessed at baseline and 1736 of them at follow-up. Teachers delivered lessons, which included behavioural contracting and budgeting of SMU and SDC. Daily SMU, PA behaviours, SDC, and breakfast patterns were assessed via parental questionnaire. After one-year intervention, significant effects were found in the intervention group for SMU of girls, children without migration background, and children with parents having a low education level. In the control group, second grade children skipped breakfast significantly more often. Tendencies but no significant differences were found for PA and SDC. This intervention seems to affect groups, which are usually hard to reach, such as children of parents with low education levels, which shows that active parental involvement is vital for successful interventions.

1. Introduction

One of the rising concerns in Western countries is the high prevalence of childhood obesity which has mainly been attributed to a constant decrease in physical activity levels and increased energy intake [1, 2]. Although recent research suggests a stabilisation in prevalence rates of overweight and obese children in developed countries [3], evidence shows that once obesity is established, it is problematic to reverse [4]. Additionally, it has been shown that obesity during youth is likely to follow through to adulthood [5].

Correspondingly, childhood obesity has been pronounced the main childhood health issue in developed countries [6] with consequences for the physical as well as psychological well-being for the affected children. Hence, obesity during childhood is a risk factor for subsequent chronic diseases in later life which should not be neglected [7, 8].

Sufficient physical activity and a well-balanced diet on the other hand are essential for normal growth and development [9] and play an important role in the prevention of increased weight and obesity [10]. Research shows that children lead an active lifestyle because of factors which they acquired as habits in early life and therefore profit from health benefits in adulthood [11]. Also, skipping breakfast is associated with higher rates of overweight and obesity in children [12] and especially the consumption of sugar-sweetened beverages has been identified as the most consistent dietary factor, which is associated with subsequent increases in weight status and fatness in children [13].

Healthcare professionals, governments, and many communities have long recognised childhood obesity as an increasing health problem and therefore have developed various programmes targeting inappropriate weight gain by reducing energy-dense foods and sedentary time (mainly television viewing) as well as increasing the daily amount of physical activity children engage in [14, 15].

Since several studies have shown positive and preventive effects of an active lifestyle during childhood on later life [7, 16, 17] and also that sedentary behaviour in childhood is maintained as an adult [11, 18] health promotion has to start early in life.

Therefore, schools have been identified as providing an ideal environment for the promotion of health-enhancing behaviours [19]. Based on the results of a recent review, Waters et al. [20] suggest that for interventions to be successful, they have to be integrated into the school curriculum and include amongst others "healthy eating, physical activity, and body image" [20, page 128] as well as support for teachers and parents. Furthermore, interventions intended to last longer than one year are more likely to become integrated into curriculum, school and parents activities than shorter interventions [21] and therefore are more promising to increase knowledge and behaviours which contribute to a healthy lifestyle and enhanced quality of life in the long term.

One programme incorporating those aspects is "Join the Healthy Boat - Primary School." This low-threshold programme promotes a healthy lifestyle in primary school children in Baden-Württemberg, southwest Germany, and started in 2009 (for more detailed information see [22]). The programme's contents and materials are integrated into the primary school curriculum focusing on health promoting behaviour change towards more physical activity, less time spent with screen media, and a more healthy diet, especially targeting a reduction of soft drink consumption and breakfast skipping. The teaching materials, developed in collaboration with experienced primary school teachers, are delivered by the classroom teacher and promote healthy and active alternatives, which children are offered to choose in order to lead a healthier lifestyle. The prepared, ready-to-use teaching units include lessons that increase awareness (e.g., about the amount of sugar in some drinks), teach health-related topics such as "why does my body need physical activity?" and offer ideas and alternatives for leisure activities children can engage in without the use of screen media.

In order to know whether the implementation and intended outcomes were achieved a large-scale evaluation had to be carried out. The purpose of this study, therefore, is to investigate the children's behaviours after a one-year intervention in respect of the programme's key aspects: an increase of physical activity, a decrease in time spent with screen media as well as more regular breakfast, and a reduction of the consumption of sugar-sweetened beverages.

2. Materials and Methods

2.1. Intervention and Evaluation Design. The evaluation of this school-based, teacher-centred intervention, which is based on Bandura's social cognitive theory [23], is a prospective, stratified, cluster-randomised, and longitudinal study including an intervention group and a control group. After baseline measurements had been taken, the programme's intervention was carried out in the intervention group whereas the control group followed the regular school curriculum. Follow-up measurements were taken after one year.

The intervention is based on teaching materials offering action alternatives for recreational activities (without screen media), physical activity, and a healthy diet (focussing on breakfast and soft drinks) which are integrated into the primary school curriculum. The contents are delivered by the classroom teacher after taking part in a tripartite training course. Further detailed information on teaching materials and their contents have been published elsewhere [22]. In order to recruit the participating school and pupils, all primary schools of the state of Baden-Württemberg (southwest Germany) received written information about the programme and the intervention study, asking teachers to participate. Interested teachers then contacted the study group. Participation in the programme was voluntary and participating teachers had to agree with the randomisation process.

Stratification of randomisation was carried out on grade level based on information about the distribution of participating teachers within the different schools. Stratification according to number of classes and grade levels was realised on six different levels. Cluster-randomisation was carried out on school level into intervention and control groups. A detailed insight of the randomisation and stratification is provided elsewhere [22].

Approval for the study was obtained from the University's Ethics Committee, the Ministry of Culture and Education, and was provided in accordance with the Declaration of Helsinki. In addition, the study is registered at the German Clinical Trials Register (DRKS-ID: DRKS00000494).

2.2. Participants. 1943 primary school children (7.1 ± 0.6 years; 51.2% male) in 154 classes (80 classes in the intervention group; 74 classes in the control group), who participated in the evaluation study of the programme, were assessed at baseline (Autumn 2010) and 1736 of them at follow-up (Autumn 2011). Prior to data collection, parents provided written and informed consent and children provided their assent to take part in the study.

2.3. Instruments. Anthropometric measurements such as children's height (cm) and body mass (kg) were taken by trained technicians according to ISAK Standards [24] using a stadiometer and calibrated electronic scales (Seca 213 and Seca 862, resp., Seca Weighing and Measuring Systems, Hamburg, Germany). The children's BMI was calculated as weight divided by height squared and converted to BMI percentiles (BMIPCT) using German reference data [25] to define their weight status. Cut-off points for overweight children were determined above the 90th percentile and for obese children above the 97th percentile.

All other parameters such as daily screen media time, physical activity behaviours, soft drink consumption and breakfast patterns as well as parental education levels, height, and body weight were assessed using a parental questionnaire. The included questions were based on the German Health Interview and Examination Survey for Children and Adolescents (KiGGS), which recently assessed health behaviour in 18,000 German children and adolescents [26].

Parental weight status was classified using WHO standards [27] with a cut-off point of 25 kg/m^2 defining overweight.

2.4. Data Analysis. Statistics were performed using SPSS Statistics 21 (SPSS Inc., Chicago, IL, USA) with a significance level set to $\alpha < 0.05$. Descriptive statistics were calculated (mean values and standard deviations). For categorical data, Fisher's exact test was used for the detection of group differences at baseline. For inference statistical analysis, physical activity was dichotomised by engagement on most days per week (i.e., four days or more) of at least 60 minutes of moderate to vigorous physical activity (MVPA). Time using screen media (TV, PC, and game consoles) was dichotomised using a cut-off point of one hour per day based on the recommendations of the American Academy of Paediatrics [28]. Parental data providing information on soft drink consumption were dichotomised by consuming soft drinks more than once versus less than once per week (median split). The frequency of having breakfast prior to going to school was also dichotomised as "often/always" versus "never/rarely." Subsequently, logistic regression adjusted for baseline measures was used to determine odds ratios (OR) for all health outcomes.

3. Results

A summary of the participant's baseline sociodemographic, anthropometric, and lifestyle characteristics is shown in Table 1. No significant gender differences were found for height, weight, and BMIPCT. The prevalence of overweight including obesity is 9.0% and of obesity alone 4.0% of children.

Group comparing to check if the randomisation was successful revealed no differences between control and intervention groups for all relevant variables with the exception of migration background, which was significantly higher in the intervention group ($P \leq 0.01$).

3.1. Physical Activity. At baseline, children engaged in 60 minutes of MVPA on 2.74 (±1.66) days per week. Further, 31.9% and 22.2% of boys and girls, respectively, spent at least 4 days per week being moderately to vigorously physically active for at least 60 minutes. 4.2% of children reached the 60 minutes of MVPA on seven days per week, which are recommended by the WHO [29]. At baseline, no differences between control and intervention groups were observed. Boys, however, showed significantly more activity than girls ($P = 0.001$).

At follow-up, children engaged in 60 minutes of MVPA on 2.82 (±1.61) days per week and 34.1% and 21.5% of boys and girls, respectively, spent at least 4 days per week being moderately to vigorously physically active for at least 60 minutes. 3.7% of children reached the recommended 60 minutes of MVPA on seven days per week.

Also, after one year, no significant differences in the amount of physical activity were found between control and intervention groups (Table 3).

However, there is a tendency towards more physical activity in the intervention group and a slight reduction of physical activity in the control group (Table 2). This tendency was especially pronounced if only considering boys, although statistical significance was not reached (OR = 1.34, $P = 0.083$, 95% CI [0.96; 1.88]).

3.2. Screen Media Consumption. Baseline results of screen media use show that 15.4% and 11.2% of boys and girls, respectively, spent a minimum of one hour per day using screen media, including television, computer/laptop, and video games. Boys spent significantly more time with screen media than girls ($P = 0.01$). No group differences at baseline between control and intervention group could be observed.

After one year, the proportion of children using screen media for at least one hour daily remained virtually unchanged with 15.6% of boys and 11.5% of girls. The gender difference, which could be observed at baseline, persisted, but examining the entire cohort, the intervention showed no significant effects on the time children spend in front of screen media (Table 3).

Nevertheless, there is a tendency towards less screen media use in the intervention group, whereas the opposite trend could be observed in the control group (Table 2).

Further, considering girls and boys separately, there is a significant difference between control and intervention groups with only girls in the intervention group using significantly less screen media per day than their counterparts in the control group (OR = 0.58, $P = 0.04$, 95% CI [0.35; 0.96]). Additionally, significant positive intervention effects on screen media consumption have been found in children (boys and girls) without a migration background as well as in children whose parents have a low education level (OR = 0.61, $P = 0.043$, 95% CI [0.38; 0.98] and OR = 0.64, $P = 0.032$, 95% CI [0.43; 0.96], resp.).

3.3. Soft Drink Consumption and Breakfast. Investigating children's soft drink consumption, at baseline, 24.6% of boys and 22.6% of girls drank sugar-sweetened beverages at least once per week. Neither a significant gender difference nor a difference between control and intervention groups could be observed at baseline.

Similarly, at follow-up, there was no significant difference between control and intervention groups (Table 3). Even though, a reduction of soft drink consumption could be seen in both groups. However, the decline in the intervention group was by trend greater than that in the control group (Table 2).

Data on children's breakfast behaviour show that at baseline 12.9% of children went to school without or rarely having breakfast before they leave. There was a significant gender difference with 15.4% of girls and 10.6% of boys skipping breakfast prior to school ($P = 0.001$).

At baseline and at follow-up, no significant differences between control and intervention group were found. Nonetheless, a tendency towards more children skipping breakfast could be observed in the control group at follow-up whereas in the intervention group the number of children who went to school without breakfast remained virtually the same (Table 2).

However, considering children in grade one and grade two separately, this trend becomes a significant difference

Table 1: Baseline characteristics of participants in the “Join the Healthy Boat” study.

	Missing Values	Intervention ($n = 954$)	Control ($n = 782$)	Total ($n = 1736$)
Age, years [m (sd)]		7.09 (0.63)	7.06 (0.63)	7.08 (0.63)
Boys, *n* (%)		475 (49.8)	411 (52.6)	886 (51.0)
Migration background, *n* (%)	244	280 (34.2)*	183 (27.2)*	463 (31.0)
Anthropometry				
BMI, [m (sd)]		16.03 (2.22)	15.92 (2.03)	15.98 (2.14)
BMIPCT, [m (sd)]		48.87 (27.82)	48.12 (27.49)	48.53 (27.67)
Overweight and obesity, *n* (%)		95 (10.0)	70 (9.0)	165 (9.0)
Parental characteristics				
Tertiary family educational level, *n* (%)	270	268 (33.2)	208 (31.6)	476 (32.5)
Overweight (mother), *n* (%)	301	247 (31.5)	195 (30.0)	442 (30.8)
Overweight (father), *n* (%)	393	460 (61.9)	355 (59.2)	815 (60.7)
Health and lifestyle characteristics				
MVPA on ≥4 days/week ≥60 min/day, *n* (%)	266	216 (26.8)	183 (27.6)	399 (27.1)
Screen media ≥1 h/day, *n* (%)	207	122 (14.5)	83 (12.0)	205 (13.4)
Soft drinks ≥1 time/week, *n* (%)	198	207 (24.5)	156 (22.5)	363 (23.6)
Skipping breakfast, *n* (%)	196	110 (13.0)	89 (12.8)	199 (12.9)

m (sd): mean (standard deviation); BMI: body mass index, BMIPCT: BMI percentiles, and MVPA: moderate to vigorous physical activity.
*Significant difference, $P \leq 0.05$.

Table 2: Baseline and follow-up results for physical activity, screen media consumption, soft drink consumption, and breakfast skipping.

	Intervention ($n = 954$)	Control ($n = 782$)	Total ($n = 1736$)
Physical activity[a]			
Baseline, *n* (%)	216 (26.8)	183 (27.6)	399 (27.1)
Follow-up, *n* (%)	231 (29.1)	177 (26.5)	408 (27.9)
Screen media consumption[b]			
Baseline, *n* (%)	122 (14.5)	83 (12.0)	205 (13.4)
Follow-up, *n* (%)	104 (12.7)	100 (14.6)	204 (13.6)
Follow-up (girls only)*, *n* (%)	40 (9.8)	47 (14.2)	87 (11.3)
Follow-up (no migration background)*, *n* (%)	49 (9.3)	62 (12.8)	111 (11.2)
Follow-up (low parental education)*, *n* (%)	70 (13.9)	75 (17.3)	145 (16.1)
Soft drink consumption[c]			
Baseline, *n* (%)	207 (24.5)	156 (22.5)	363 (23.6)
Follow-up, *n* (%)	178 (21.8)	152 (22.1)	330 (22.0)
Breakfast skipping[d]			
Baseline, *n* (%)	110 (13.0)	89 (12.8)	199 (12.9)
Follow-up, *n* (%)	101 (12.4)	100 (14.5)	201 (13.4)
Follow-up (grade 2 only)*, *n* (%)	42 (10.8)	53 (16.6)	95 (13.5)

[a]MVPA on ≥4 days/week ≥60 min/day (MVPA: moderate to vigorous physical activity); [b]screen media ≥1 h/day; [c]soft drinks ≥1 time/week; [d]regular breakfast skipping.
*Significant difference, $P \leq 0.05$.

Table 3: Behavioural outcomes at follow-up for the intervention group.

	n^a	OR^b	P	95% CI
Physical activity				
MVPA on ≥4 days/week ≥60 minutes MVPA	1386	1.18	0.19	[0.92, 1.52]
Screen media use				
Screen media ≥1 h/day	1471	0.75	0.10	[0.53, 1.06]
Soft drink consumption				
Soft drinks ≥1 time/week	1475	0.96	0.76	[0.72, 1.28]
Breakfast habits				
Skipping breakfast	1480	0.86	0.47	[0.58, 1.29]

OR: odds ratio, CI: confidence interval, and MVPA: moderate to vigorous physical activity; [a]only cases with baseline and follow-up data; [b]adjusted for baseline outcomes.

for children in grade two: the second-graders in the control group skipped breakfast significantly more often than those in the intervention group (OR = 0.52, $P = 0.024$, 95% CI [0.30; 0.92]).

4. Discussion

This cluster-randomised effectiveness trial of a low-threshold, teacher-centred health promotion intervention led to a significant decrease of screen media use in girls and children without migration background compared to children receiving no intervention. "Join the Healthy Boat" also significantly improved children's breakfast behaviours in second grade and led to a tendency towards more overall physical activity in the intervention group.

Apart from that tendency, no significant effects in children's regular physical activity could be observed after the first year of this school-based intervention, which is consistent with previous interventions [30–32]. However, since physical activity is a primary determinant of optimal growth and health in children [33] and school has been determined as an important environment for physical activity [19], numerous recent studies and interventions have tried to increase children's activity levels during the past years. The approaches and methods of those interventions—as well as their results—differ widely, including the placement of a full-time member of staff in the schools, who is dedicated to facilitating healthy living [33] or the use of a so-called buddy system where older peers deliver health messages [34].

The present programme aimed at children changing their activity behaviours because of the choices they make, without reminders or additional PE sessions. Although, previous research has shown that social environmental factors such as teacher encouragement are positively related to children's physical activity levels [35, 36]. The "Join the Healthy Boat" intervention, however, focuses on delivering alternatives, so children learn about different ways and activities to spend their free time more actively. A longer lasting and more intense intervention might have shown more positive physical activity results, which was suggested by Ploeg and colleagues [33], comparing an intervention lasting one year compared to three years.

Another target of this intervention was to reduce children's sedentary time using screen media. Significant positive intervention effects were found in girls and children without a migration background as well as in children whose parents have a low education level but not boys or children with migration background. This is in accordance with a recent meta-analysis of 16 intervention programmes trying to reduce children's screen time which showed that around 60% of interventions result in positive effects on children's sedentary time [37]. The authors also noted that—the same as in this study—all programmes combined the reduction of screen time with other components. It was highlighted that for a successful intervention and reduction of screen time parental involvement is vital [37] and current research suggests that interventions show better results if they include a family component [38]. Apart from offering children active alternatives for sedentary behaviour, in the "Join the Healthy Boat" programme, screen time reduction was mainly targeted by letters to parents and the so-called family homework, which asked parents to spend a "screen-free weekend" with their children. In the letters, parents were introduced to TV guidelines and age-appropriate time limits for screen media use but were also offered alternatives of what to do on such a "screen-free weekend." This may be one of the reasons why children without migration background benefited from this intervention compared to children with migration background. Although the letters to parents were provided in Turkish and Russian as well as German, parents from other countries may have not received or understood the given information. Similarly, to parents with a low educational level the given information and guidelines may have been news so they then might have actually tried to control their children's screen media use to a certain extent. However, the intervention also showed significantly reduced screen media use in girls but not boys, which is contrary to other research [39]. But it has further been suggested that interventions as this one are effective in changing children's behavioural capability (which was not assessed in this study) but do not necessarily result in a shift in behaviour [39], which might explain the lack of overall effects regarding screen media use.

The third aspect of this programme was a reduction of sugar-sweetened beverages and breakfast skipping. In compliance with recent Danish research [40], no differences between the groups were observed in the amount of sugar-sweetened beverage intake, which is possibly due to the fact that soft drink consumption was only communicated to parents using letters and no family homework. Skipping breakfast, however, was tackled using family homework (having a healthy family breakfast together) as well as joint breakfast in class (twice a year). It is well known that parents play an important role in the development of healthy breakfast behaviours [41] and parental breakfast intake has been shown to be associated with the breakfast intake of their children [42]. Children in this study were having breakfast a little more regularly than that reported in other researches [12], where skipping breakfast was also associated with increased weight, which was not assessed in this study. In the present study, children in second grade skipped breakfast significantly less often than their counterparts in the control group showing positive intervention effects.

Since recent findings suggest that it is at or around the first school year when overweight in German children particularly increases [43], it is vital to start health promotion early. For school-based interventions the use of a comprehensive approach for health promotion is recommended [44] and Vasques et al. [45] suggest interventions that focus on children's physical activity as well as their diet and involve their parents in order to be successful.

Although this study has a large sample size, which increases the likelihood of having sufficient power to detect intervention effects, some aspects should be considered when interpreting these findings. The use of parental report measures of physical activity, screen media use, and drinking/eating behaviour and the associated recall biases is a limitation of this study. Furthermore, participating in this study may have led to an increased social desirability bias with regard to the measured variables as awareness was raised for the importance of physical activity and other health behaviours. Also, the present intervention was very low "dose" and delivered by regular class teachers rather than external staff which also may lower the likelihood of the "Hawthorne" or observer effect. Further it should be noted that the effects of health promotion are usually not detected in a short time frame such as the one of the present evaluation study. The "Join the Healthy Boat" intervention covers the entire period of primary school in Germany which lasts four years. In contrast, the corresponding study could only investigate one year because the waiting control group could not deny the intervention any longer. Even though a major strength of this study is the randomised controlled design with a control group, the teachers in that group were also very health conscious and have not been "inactive," which led to a strong contamination with other efforts to promote pupils' health in the control group. Moreover, according to a microsimulation model, health gains from interventions targeting children occur in the long term [46].

5. Conclusions

Although, only using a low-dose teacher-centred approach, the school-based health promotion programme "Join the Healthy Boat" managed to achieve significant positive effects in the reduction of screen media use (in girls and children without migration background and parents with a low education level only) and breakfast skipping (second grade children only) as well as a tendency towards more physical activity in the intervention group. Whilst some effects were rather small, the intervention seems to affect even groups which are usually hard to reach such as children of parents with low education levels. This shows that active parental involvement is vital for a successful intervention and should be intensified and demanded.

Since most behaviours are difficult to change within one year, further research should include investigations into the level of intensity and length of time an intervention needs to be of to show lasting effects on behaviour change. Further, the kind and level of parental involvement would be of interest for future studies in order to improve health promotion programmes.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Using the Medical Research Council Framework for the Development and Evaluation of Complex Interventions in a Theory-Based Infant Feeding Intervention to Prevent Childhood Obesity: The Baby Milk Intervention and Trial

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Introduction. We describe our experience of using the Medical Research Council framework on complex interventions to guide the development and evaluation of an intervention to prevent obesity by modifying infant feeding behaviours. *Methods*. We reviewed the epidemiological evidence on early life risk factors for obesity and interventions to prevent obesity in this age group. The review suggested prevention of excess weight gain in bottle-fed babies and appropriate weaning as intervention targets; hence we undertook systematic reviews to further our understanding of these behaviours. We chose theory and behaviour change techniques that demonstrated evidence of effectiveness in altering dietary behaviours. We subsequently developed intervention materials and evaluation tools and conducted qualitative studies with mothers (intervention recipients) and healthcare professionals (intervention deliverers) to refine them. We developed a questionnaire to assess maternal attitudes and feeding practices to understand the mechanism of any intervention effects. *Conclusions*. In addition to informing development of our specific intervention and evaluation materials, use of the Medical Research Council framework has helped to build a generalisable evidence base for early life nutritional interventions. However, the process is resource intensive and prolonged, and this should be taken into account by public health research funders. This trial is registered with ISRTCN: 20814693 Baby Milk Trial.

1. Introduction

While the aetiology of obesity has been simplified to an imbalance between energy intake and energy expenditure over a prolonged period, the psychological, social, physiological, environmental, and other factors causing this imbalance are complex [1]. A complex problem does not always necessitate a complex intervention, but complex interventions, targeting multiple causal factors and the interactions between them, may be necessary [2]. Complex interventions are often not systematically developed, specified, or reported [3]. Following a systematic process in the development and evaluation of a complex intervention may help in understanding the processes underlying any observed intervention effects and for whom and in which settings interventions work, to inform and improve the development, evaluation, and implementation of future interventions.

To address some of the complexities in defining, developing, and evaluating complex interventions, a number of frameworks have been proposed. These include Intervention Mapping [4, 5], RE-AIM (reach, efficacy, adoption, implementation and maintenance) [6, 7], Precede-Proceed [8], and Logic Models [9, 10]. More recently, the Medical Research Council (MRC) framework for developing and evaluating complex interventions originally published in 2000 [11] and updated in 2008 [2] has been recommended (Figure 1). The 2000 MRC framework suggested a model based on the phases conventionally used in the evaluation of new drugs—from initial preclinical research through to postmarketing surveillance [11]. The updated 2008 MRC framework provides a more flexible, less linear model of the process with greater attention to early phase piloting and development work [2].

The aim of this paper is to describe our experience of using the 2008 MRC framework to develop and evaluate a theory-based, behavioural infant feeding intervention aimed at preventing childhood obesity, including benefits and challenges of using this framework.

2. Methods

The activities we undertook and the stages of the 2008 MRC framework they map onto are shown in Table 1 and presented in more detail below.

2.1. Developing a Complex Intervention

2.1.1. Identifying the Evidence Base

Review of the Epidemiological Evidence for Early Life Risk Factors Contributing to Childhood Obesity. The review highlighted the importance of excess energy intake resulting in excess weight gain during infancy [12–14], formula-feeding, and poor weaning practices in the development of obesity [15]. Randomised trials in small-for-gestational age and preterm infants showed that greater dietary energy content increased risk of obesity and metabolic disease in later life [16, 17]. In 2004, the World Health Organization and other international bodies reduced the recommended average energy requirements (AER) for infants by around 15 to 20% [18] and these energy requirements form the basis of the Baby Milk intervention. Babies who are fed formula-milk are more likely to show rapid weight gain during infancy than breastfed babies [19], possibly as a result of higher energy intake. In addition their mothers have a number of demographic characteristics that are associated with obesity risk (lower age, education, and socioeconomic status) and hence the intervention targets formula-fed babies (54% at 1 week age and 77% at 6 weeks age in UK [20]) through their mothers.

Systematic Review of Parent's Experiences of Bottle-Feeding. Having identified formula-fed babies as a high-risk group and excess energy intake amongst this group as a potential target for intervention, we sought to increase our understanding of the behaviours associated with excess energy intake by conducting a systematic review of the quantitative and qualitative literature around parents' experiences of bottle-feeding [21]. The review suggested that mothers who bottle-fed experienced negative emotions such as guilt, anger, worry, uncertainty, and a sense of failure. This emphasised the need for our intervention to be delivered with empathy and in a collaborative participant-centred style. Mothers reported receiving little information on bottle-feeding and did not feel empowered to make decisions. Mistakes in feed preparation and frequent formula-milk changes were common.

Systematic Review of Determinants of Early Weaning. We undertook a systematic review of the determinants of early weaning and inappropriate introduction of cow's milk to increase our understanding of why parents do not follow infant feeding recommendations [22]. Strong evidence was found for six maternal determinants of early weaning: young age, low education and socioeconomic status, absence/short duration of breastfeeding, smoking, and lack of information or advice from healthcare providers. The results of this review mirror the much larger body of evidence on determinants of breastfeeding [23–25]. Of these determinants, improving the advice and support given by healthcare providers appeared to be the area most amenable to intervention in the short term.

Systematic Review of Interventions to Prevent Obesity in Young Children. A 2011 Cochrane review on interventions to prevent obesity in children and adolescents identified 55 studies [26]. Only eight of these were targeting children aged 0–5 years and these studies showed the largest intervention effects, but none were specific to infancy. A search for "childhood obesity prevention" trials listed on registers of active and archived controlled trials (http://www.clinicaltrials.gov and http://www.controlled-trials.com) was conducted and nine trials in this age group were identified [27–35]. However none of them targeted energy intake from formula-milk, the focus of the baby milk intervention.

2.1.2. Identifying/Developing Appropriate Theory. A number of psychological factors (e.g., beliefs and emotions) and environmental factors are involved in learning new behaviours and changing existing behaviours. Theories or models provide an overarching framework for the psychological and environmental factors that explain behaviours to be targeted by an intervention. As there were no behavioural interventions specifically targeting formula-milk feeding, this stage included a review of the literature on psychological theories and behaviour change techniques that had shown some success in improving dietary behaviours.

Social Cognitive Theory (SCT). We identified Bandura's social cognitive theory [36] as a useful theory to inform mediators along the hypothesised causal pathways of intervention effects. The theory has been shown to predict other dietary behaviours, including fruit and vegetable intake in children [37], and has been used to develop interventions to improve breastfeeding practices [38] and dietary behaviours in adults [39, 40].

The key constructs of SCT are as follows.

Perceived Self-Efficacy. This refers to a person's belief or confidence in their ability to successfully perform a specific task or behaviour. High perceived self-efficacy is related to a feeling of being "*in control*" and a belief that "*I will be able to*

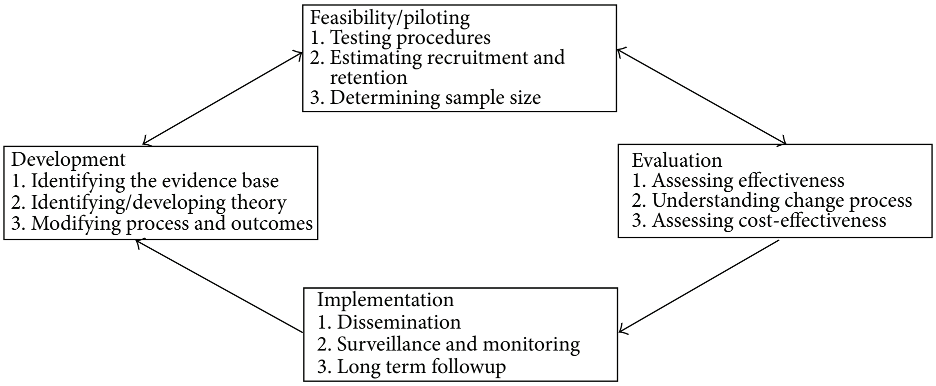

Figure 1: Key elements of the development, evaluation, and implementation process of complex interventions. Source: [2].

continue to perform the behaviour even in the face of difficult obstacles or stressful situations."

Outcome Expectancies. These are person's thoughts or beliefs about the results or consequences of certain behaviour. Outcome expectancies can be either positive or negative and may be related to physical, social, and self-evaluative outcomes, that is, outcomes related to physical health, feedback from others, and feelings about oneself.

Sociostructural Factors. Environmental factors are referred to as sociostructural factors. These include all the factors outside of the person that might affect their ability to perform the target behaviour but are not necessarily beyond the person's control. An example of a sociostructural facilitator might be a local support group. A sociostructural barrier might be a grandparent or child minder unwilling to follow recommendations. Hence, the identification of barriers and facilitators for performance of the behaviour are techniques used in the intervention (Table 2).

Implementation Intentions (IIs). While SCT is promising in terms of strengthening motivation, it has been shown that good intentions do not always translate to behaviour change; hence we added implementation intentions (IIs). IIs have been shown to bridge the gap between motivation and action [41]. They commit an individual to a specific course of action when certain environmental conditions (barriers or facilitators) are met. The environment therefore acts as a cue to action and helps the individual to achieve their goal. IIs are "if. . .then. . .plans" specifying when, where, and how the person will act on their intentions and perform the behaviour and link the behaviour to specific cues [42].

Behaviour Change Techniques (BCTs). While theories provide a framework to understand how behaviours targeted in the intervention change, behaviour change techniques (BCTs) constitute the active content of interventions. We selected behaviour change techniques (BCTs) informed by the theoretical basis of our intervention (SCT and IIs) with evidence of effectiveness in changing dietary behaviours [43]. We used Abraham and Michie's taxonomy [44] to define the BCTs and operationalize them as intervention strategies in the intervention protocols (Table 2). The intervention aims to encourage parents to reduce the amount of formula-milk feeds, recognise infant satiety cues, not to respond to nonhunger related fussiness by feeding, wean babies onto a healthy diet, and recognise if their babies are gaining excess weight. Table 3 summarises the contacts during which core intervention contents are used.

Qualitative Studies. Following initial development of the intervention, qualitative studies were conducted to assess the acceptability and feasibility of intervention delivery and appropriate changes to the intervention materials were made. Psychologists, dieticians, and doctors were interviewed and in addition, interviews and focus groups were conducted with relevant stakeholders-mothers (recipients of the intervention) and healthcare providers (health visitors and midwives who would deliver the intervention). An iterative process was used to refine the intervention [45]. One example of how this work informed intervention development is that "healthy growth" rather than "obesity prevention" was emphasised in the resources and communication messages. Furthermore, mention of breastfeeding being best was removed as mothers said this was not appropriate for a formula-feeding intervention. The studies also highlighted the need for repeated contacts delivered in an empathic, nonjudgemental, client-centred communication style and supported by written materials.

2.1.3. Modelling Process and Outcomes. A causal modelling approach [46] was used to link behavioural determinants causally through behaviour to physiological variables and health outcomes. Process and outcomes measures were mapped onto the causal pathway (Figure 2).

While validated measures existed to assess most variables along the causal pathway, we had to develop and validate a questionnaire to assess changes in the key behavioural determinants targeted by the intervention (maternal attitudes, SCT constructs targeted by the intervention, and milk feeding behaviour) [47]. The questionnaire showed good reliability (% agreement above 70% for 51/57 items, Kappas 0.37–1) and reasonable validity (% agreement above 66% for 39/57 items) and internal consistency (Cronbach's alphas 0.51, 0.79,

Table 1: Studies undertaken mapped to the phases of the MRC framework [2].

Definition	Studies undertaken
(1) Developing a complex intervention	
(1.1) Identifying the evidence base by carrying out a systematic review	(i) Reviewed the epidemiological evidence for early life risk factors for obesity. (ii) Improved understanding of the target behaviour. (a) Systematic review of parents' experiences of bottle-feeding to understand how parents decide on quantities and frequency of formula-milk feeds. (b) Systematic review of determinants of early weaning: "Determinants of early weaning and early use of cow's milk" identified determinants of noncompliance with infant feeding recommendations. (iii) Identified existing systematic reviews and checked the controlled trials register for trials of interventions during infancy.
(1.2) Identifying/developing appropriate theory by drawing on existing evidence and theory, supplemented if necessary by primary research, for example, interviews/focus groups with "stakeholders", that is, those targeted by the intervention or involved in its development or delivery	(i) Literature review and team discussions to decide on theory, behaviour change techniques, and intervention strategies. (ii) Qualitative studies with all stakeholders to refine intervention content. These included interviews and focus groups with mothers (recipients of the intervention) and healthcare providers (who would deliver the intervention). In order to optimise the intervention, an iterative process was used with involvement of mothers, behavioural scientists, doctors, midwives, and health visitors.
(1.3) Modelling process and outcomes by using a "causal modelling approach" that could include a range of primary and desk based studies to design the intervention, identify suitable measures, and predict long-term outcomes.	(i) Used a causal modelling approach to link "behavioural determinants" to "behavior" and "short-term and long-term outcomes". (ii) Developed and validated a questionnaire for use in the trial to assess change in key constructs along the causal pathway targeted by the intervention.
(2) Assessing feasibility and piloting methods	
(2.1) Testing procedures for their acceptability, compliance, and intervention delivery	(i) Tested components independently for feasibility and acceptability and final adaptation of the intervention. (ii) 1 year pilot trial of combined intervention components.
(2.2) Estimating recruitment and retention and identifying potential barriers to these, using a mixture of qualitative and quantitative methods	(i) Recruitment through post-natal wards, GPs, Health Visitors, midwives, pharmacies, NHS database, charities, and the media to identify most efficient and effective methods. (ii) Pilot trial over 1 year.
(2.3) Determining sample size by anticipating the effect sizes in a pilot study	Pilot trial was too small and no previous trials in this area hence used data from observational studies to estimate sample size.
(3) Evaluating a complex intervention	
(3.1) Assessing effectiveness by using a randomised controlled trial where possible, choosing the primary and a range of secondary outcomes, and collecting data on predictors or mediators of effect and any possible adverse effects	Set up explanatory RCT (ISRTCN number 2081469). Primary outcome is growth-related and data on a number of secondary outcomes along the causal pathway are also collected. Weight faltering in the babies and reduced quality of life in mothers monitored real time as potential adverse effects reported to independent data monitoring committee.
(3.2) Understanding change processes provide insights into why an intervention fails unexpectedly or why a successful intervention works and how it can be optimised. Process evaluation nested within a trial can be used to assess fidelity and quality of intervention delivery, clarify causal mechanisms, and identify contextual factors associated with variations in outcomes. Process evaluations should be conducted to the same high standards and reported just as thoroughly as evaluation of outcomes	(i) Intervention fidelity assessment using prespecified checklists. (ii) Qualitative study nested within the trial-individual interviews with mothers in the intervention and control groups and intervention facilitators to explore how feeding decisions are made, how the intervention might work (or why it may not work) and can be optimised, to identify key ingredients that could be included in future interventions and other contextual factors. (iii) Mediation analyses to understand how the intervention achieved any effects.
(3.3) Cost-effectiveness analyses should be included if at all possible, so that the results are useful to decision makers	Cost-consequence analysis planned and data collection on health service utilisation and maternal quality of life in addition to cost of delivering the intervention.
(4) Implementation and beyond	

Table 1: Continued.

Definition	Studies undertaken
(4.1) Dissemination by publication in peer-reviewed literature and also communication with policy makers	Peer reviewed publications, conference presentations, public engagement activities, newsletters, and open access web deposition at the end of the trial.
(4.2) Surveillance, monitoring, and long-term outcomes to measure rare or long-term impacts, using routine data sources and record linkage or by recontacting participants	Consent to recontact participants and access routinely collected health and anthropometry data. If intervention is shown to be effective, process and outcome data could inform a future pragmatic trial.

Table 2: Behaviour change techniques and intervention strategies used in the baby milk intervention [44].

Technique[a]	Definition[a]	Intervention strategies
(1) Provides information on consequences	Information about the benefits and costs of action or inaction, focusing on what will happen if the person performs the behaviour.	Leaflet explains link between feeding behaviours, rapid weight gain and risk of obesity. This information is reinforced and participant understanding about the information checked during 3 face-to-face and 2 telephone contacts.
(2) Prompts intention formation	Encouraging the person to decide to act or set a general goal.	Leaflet encourages lower guidelines for formula-milk feeding and suggests a general feeding plan. Develop a personalised feeding plan (PFP) in intervention contacts.
(3) Prompts barrier identification	Identifying barriers to performing the behaviour and plan ways of overcoming them.	Identify barriers using cost-benefit analysis, motivation ruler and confidence ruler. Formulation of "if. . .then. . ." plans to overcome barriers for example, crying between feeds ("If she cries at night, then I will offer her a dummy")
(4) Prompts facilitator identification	Identifying facilitators to performing the behaviour and plan ways to use them to overcome barriers.	Cost-benefit analysis, motivation ruler and confidence ruler.
(5) Provides general encouragement	Praising or rewarding the person for effort or performance without this being contingent on specified behaviours or standards of performance.	Praise all attempts at following guidelines. Good communication skills: building rapport, empathy, active listening, nonjudgemental, and client-centred.
(6) Sets graded tasks	Setting easy task and increasing difficulty until target behaviour is performed.	Monthly contact to encourage mothers to set small achievable goals and revise them. Review of personal feeding plan (PFP) to revise goals.
(7) Provides instruction	Telling a person how to perform certain behaviour and/or preparatory behaviours.	Two leaflets and discussion about recommended feeding behaviours during 3 face-to-face and 2 telephone contacts.
(8) Models or demonstrates the behaviour	An expert shows the person how to correctly perform behaviour for example, in class or on video.	Demonstrate the correct method of formula-feed preparation at baseline visit.
(9) Prompts specific goal setting	Involves detailed planning of what the person will do, including a definition of the behaviour specifying frequency, intensity, or duration and specification of at least one context, that is, where, when, how, or with whom.	Personal Feeding plan with goals negotiated with the participant. Make these goals specific by formulating "if. . .then. . ." plans
(10) Prompts review of behavioural goals	Review and/or reconsideration of previously set goals or intentions	Review and revise goals set at each intervention contact using the Personal Feeding plan.
(11) Prompts self-monitoring	The person is asked to keep a record of specified behaviour(s) (e.g., in a diary).	Encourage participants to record amount fed in the Personal Feeding plan.
(12) Provides feedback on performance	Providing data about recorded behaviour or evaluating performance in relation to a set standard or others' performance, that is, the person received feedback on their behaviour.	Provide feedback on feeding behaviour, based on Personal Feeding plan. Provide feedback on baby's growth plotted on growth charts.
(13) Teaches to use prompts or cues	Teaching the person to identify environmental cues that can be used to remind them to perform a behavior, including times of day or elements of contexts.	Stickers on formula-milk tins which encourage lower formula-milk consumption.

[a]Labels and definitions of the behaviour change techniques are as specified in Abraham and Michie's Taxonomy of Behaviour Change Techniques [50].

Table 3: Intervention and Control contacts and content.

Timeline	Intervention group (IG)	Control group (CG)
First: face-to-face. Within 14 weeks of birth	(i) Healthy growth and nutrition leaflet. (ii) Stickers for formula-milk packets/tins with new guideline daily requirements. (iii) Education about growth charts, rapid weight gain, obesity risk. (iv) Personal feeding plan (PFP). (v) Model feed preparation if necessary.	(i) Standard Department of Health bottle feeding leaflet. (ii) General questions about formula-milk feeding, information sources, and decisions.
Second: telephone. 3-4 months (3–6 weeks later)	(i) Check understanding of key messages. (ii) Review of PFP and goal setting.	General questions about sleep and support with caring for baby.
Third: face-to-face (IG)/telephone (CG) 4-5 months (3–6 weeks later)	(i) Feedback on growth. (ii) Weaning advice. (iii) Review of PFP and goal setting.	General questions about life after the baby's birth.
Fourth: telephone. 5-6 months (3–6 weeks later)	Review of PFP and goal setting.	General questions about formula-milk changes and weaning
Fifth: face-to-face. 6-7 months (3–6 weeks later)	(i) Feedback on growth. (ii) Review of PFP and goal setting.	(i) Standard Department of Health weaning leaflet. (ii) Questions about experience of taking part in the study and research in general.

Identification of barriers and facilitator, problem solving, and "If. . .then plans" are used in all contacts. All contacts are underpinned by good communication skills. The motivation ruler and confidence ruler are used for assessment and to prompt identification of barriers and facilitators. The "cost-benefit analysis" tool is used as required to improve motivation and confidence.

and 0.90 for self-efficacy, outcome expectancies, and intention, resp.). Development of the questionnaire also influenced our thinking about intervention content.

2.2. Assessing Feasibility and Piloting Methods

2.2.1. Testing Procedures. Once developed, all the intervention materials were piloted by the intervention facilitators (trained to deliver the intervention) to ensure that the intervention was acceptable and feasible to deliver. An extensive training manual and a two-day training programme in the evidence base underlying the intervention, theories, behaviour change techniques, intervention strategies, and communication skills, including demonstration and practice with individual feedback, were piloted and adapted. For example, we initially developed long versions of intervention protocols, however, during piloting, it became clear that it was difficult for intervention facilitators to use these and we developed shorter versions with key aspects of delivery. We piloted and refined checklists for each contact with intervention and control participants to be used by the intervention facilitators to assess and promote fidelity of intervention delivery (i.e., consistent delivery across facilitators and time). For the control group participants (attention control), in order to avoid contamination, we designed protocols with questions for each contact which were organised around broad themes (Table 3).

A 1-year pilot study (March 2011–March 2012) among 78 participants provided the opportunity to engage with local providers of postnatal and primary care services in order to optimise methods for recruitment, to assess the acceptability and feasibility of the trial measures, estimate expected retention rates, and plan the resources needed for an explanatory RCT. We did not analyse the results of the pilot feasibility study separately as it continued into the full trial.

2.2.2. Estimating Recruitment and Retention. Our initial strategy to identify participants was to approach parents who were formula-feeding their baby before eight weeks of age via postnatal (midwives) and community health professionals (health visitors). To this end we spoke with midwives, infant feeding coordinators, and health visitors at their team meetings. Although this did not prove a very effective route for recruitment, partly due to the time pressures and conflicting priorities that these health professionals are faced with, it did help to raise awareness of the study and allowed us to collect information on ways to optimise recruitment and retention. For example, we extended the age of recruitment to 14 weeks, expanded our recruitment area, and offered easily accessible local clinics and/or home visit appointments.

After investigating a number of other strategies to identify participants including posters in health centres and children's centres, pharmacies, charity groups, and a local press release, we successfully applied for ethics approval for named members of our own research team to approach bottle-feeding mothers on postnatal wards directly. Since all babies are seen by their GPs for a six-week check, we also approached GPs for help with recruitment. In addition, participants were identified through the central health electronic database where a record of whether mothers were breastfeeding or bottle-feeding was made by their health visitor and a recruitment leaflet mailed to them. This multilevel approach from different professionals at different times during the first three months of infant age seemed to work well and indicated feasibility of recruitment. We did not offer any financial incentives but this could be a more effective way of recruiting,

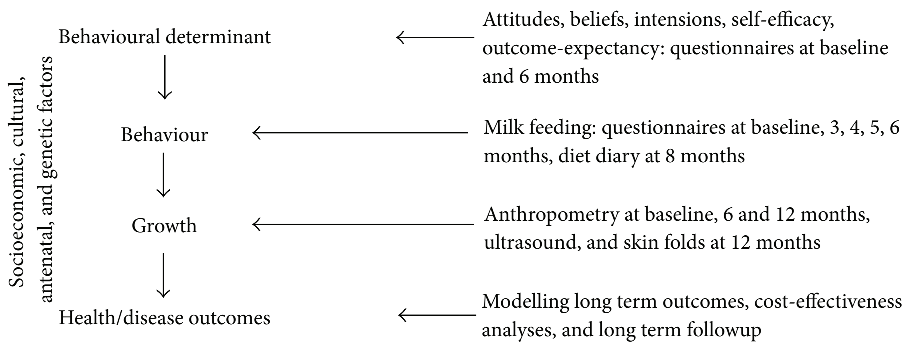

Figure 2: Hypothesised causal pathways and measures for evaluation in the Baby Milk trial.

especially the hard-to-reach group and could be considered in future studies. Ongoing data on retention was monitored and barriers to retention identified.

2.2.3. Determining Sample Size. The primary outcome was change in weight standard deviation score (SDS) from birth to age 12 months in intervention versus control groups. As there were no previous trials in this age group, we used data from observational studies of infant energy intake and growth to calculate the sample size and estimated that the target 15% lower energy intake would lead to a 0.30 SDS difference in weight [48]. Allowing for a 15% drop-out rate we needed to recruit 700 babies.

2.3. Evaluating a Complex Intervention

2.3.1. Assessing Effectiveness. We decided that the most appropriate design to evaluate the effectiveness of this behavioural intervention would be a single (assessor) blind, individually randomised controlled trial. In order to assess true "intervention" effects, we decided the control group should get the same attention as the intervention group (attention control) and offered standard advice. Due to the paucity of research in this area, in addition to assessing whether the intervention was effective, we conducted a process evaluation to improve our understanding of the determinants of infant feeding behaviours, potential causal mechanisms underlying any intervention effects observed, implementation of this complex intervention, and contextual factors [49].

2.3.2. Understanding Change Processes. The process evaluation included intervention fidelity assessment (implementation), a qualitative study and possibility for mediation analysis to illuminate contextual factors.

Implementation. Fidelity Assessment. In the Baby Milk trial, standard protocols for intervention and control group delivery were used for each contact. All planned facilitator-parent contacts (in both arms of the trial) were audiorecorded in order to assess fidelity of intervention delivery. Fidelity was promoted and contamination across the two groups minimised by assessing a random sample of audiotaped contacts using standardised fidelity checklists, followed by feedback, ongoing support over the whole period of intervention delivery, booster training sessions, and peer appraisal.

Contextual Factors. A Qualitative interview study among intervention ($n = 10$) and control ($n = 10$) group mothers and intervention facilitators ($n = 4$) explored how feeding decisions were made, to explain intervention effects, identify key ingredients that could be included in future interventions and identify contextual factors associated with variations in outcomes across participants.

Structural equation modelling can be used to test the complex relationships between mediators and outcomes, and paths through which they may exert their influence, bearing in mind the possibility of reverse causality where behaviour affects beliefs as well as vice versa [50]. For example, on the basis of SCT we hypothesize that beliefs about the health benefits for the child of following feeding recommendations (outcome expectancies) will partially mediate (explain) the relationship between confidence (self-efficacy) about following feeding recommendation and the formation of a goal.

2.3.3. Cost-Effectiveness Analyses. In order for the results to be useful to decision makers, we developed instruments to collect cost-related data, time spent in delivering the intervention and health service utilisation. The analysis plan included a cost-consequences analysis to show the cost of delivering the intervention and outcomes (proportion of infants whose weight crosses more than one centile band upwards on the growth charts (0.67 SDS) and infants of normal weight at 12 months, and probability of being normal weight as an adult using data from a meta-analysis [51]), for intervention and control groups.

2.4. Implementation and Beyond

2.4.1. Dissemination. A criticism of many trials is that their published reports do not describe the interventions in enough detail to enable them to be reproduced [52]. At the end of the trial we will make our training materials, intervention protocols, and fidelity checklists available on our website for other researchers to adapt and use.

Parents in the study and healthcare professionals who identify potential participants receive regular newsletters with key findings as they emerge. Results will be published in open access journals and reported to funders and policy makers.

2.4.2. Surveillance, Monitoring, and Long-Term Followup. Ethical permissions and consent were taken to allow future recontacting of participants and/or accessing routinely collected data.

3. Discussion

3.1. Main Findings. Use of the 2008 MRC framework has helped develop a theory- and evidence-based intervention, to specify a proposed causal pathway to change infant feeding behaviour and growth outcomes, to pilot the intervention and study procedures in order to address the main uncertainties, and to design an explanatory RCT evaluation. Careful attention to the design of the RCT means the results not only will generate evidence about the effectiveness of a replicable intervention but also will allow us to begin to elucidate the processes by which change is achieved (or why it is not). Evaluations that take account of complexity of interventions could explain outcomes better even in the absence of intervention effectiveness [53, 54].

3.2. What Is Already Known on This Topic? A number of frameworks have been proposed to aid researchers developing and evaluating complex interventions. The 2008 MRC framework suggests a comprehensive and iterative process for intervention development and evaluation.

3.3. What This Study Adds? This paper explicitly maps the various activities and developmental and piloting work to the stages of the 2008 MRC framework [2] demonstrating how the framework can be operationalised. The greater emphasis on piloting and feasibility testing in the revised MRC framework is a strength as, in our experience, intervention content and materials, evaluation tools, and recruitment strategies were significantly improved through this process.

3.4. Limitations of This Study/Framework. Using the MRC framework posed a number of challenges, the biggest being the time and resources needed. Significant resources go into the development of pharmacological and other biomedical interventions, but the development of public health interventions which do not involve the generation of intellectual property does not receive such funding. This should be something funding bodies need to consider if public health interventions are to follow the same rigorous development and evaluation process that is used in drug development. With the current model of funding, it is very difficult for researchers in most countries to use the framework due to the timescales and resources required. Consequently the evidence base may be skewed towards "high income" countries where resources for development work may be more readily available. It could be argued that the process could be shortened and some of the stages omitted, especially if the evidence-base for what is likely to work is strong. Future evidence synthesis could focus on whether studies using the MRC framework are more effective than those not using it or using other frameworks.

4. Conclusions

Careful attention to intervention development is likely to result in interventions which advance the evidence base and may be a more efficient use of limited public health research resources.

Ethical Approval

NHS ethics approval reference 10/H0305/9.

Conflict of Interests

The authors declare that they have no competing interests.

Author Contribution

Lakshman Rajalakshmi wrote the first draft and is guarantor for the paper. All authors contributed to the study design, critical revision of the paper, and approving of the final version.

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Research Article

Physical Activity in Different Preschool Settings: An Exploratory Study

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Introduction. Physical activity (PA) in preschoolers is vital to protect against obesity but is influenced by different early-life factors. The present study investigated the impact of different preschool programs and selected family factors on preschoolers' PA in different countries in an explorative way. *Methods*. The PA of 114 children (age = 5.3 ± 0.65 years) attending different preschool settings in four cities of the trinational Upper Rhine region (Freiburg, Landau/Germany, Basel/Switzerland, and Strasbourg/France) was measured by direct accelerometry. Anthropometrical and family-related data were obtained. Timetables of preschools were analyzed. *Results*. Comparing the preschool settings, children from Strasbourg and Landau were significantly more passive than children from Basel and Freiburg ($P < .01$). With regard to the family context as an important early-life factor, a higher number of children in a family along with the mother's and child's anthropometrical status are predictors of engagement in PA. *Conclusion*. More open preschool systems such as those in Basel, Freiburg, and Landau do not lead to more PA "per se" compared to the highly regimented desk-based system in France. Preliminaries such as special training and the number of caregivers might be necessary elements to enhance PA. In family contexts, targeted PA interventions for special groups should be more focused in the future.

1. Introduction

The increasing prevalence of overweight and obese preschoolers represents a challenging public health issue [1]. Early childhood obesity is associated with health consequences that may persist into adolescence and adulthood [2, 3]. Physical activity (PA) is one of the factors that influence the healthy development of children and their weight, but the majority of preschoolers tend to be inactive [4, 5]. Inactivity has been suggested as being one of the key factors contributing to the obesity epidemic in children [6, 7]. In contrast, PA participation in preschool children contributes to motor skill and psychosocial development and is vital for establishing lifelong physical activity habits during the preschool years, which could protect against weight gain later in life [6, 8].

Families with young children have been identified as a particular risk group regarding lower levels of PA of both mother and father (compared to women and men without children) [9]. This might be an important factor for establishing PA habits in young children as children's and parents' PA levels are associated [10] and therefore parents function as a role model for their children [11]. These findings at family level give rise to the question of which other early life structures could contribute to an active lifestyle in preschoolers. Because in European countries nearly 90% of preschool-age children attend some form of preschool, the increasing attendance and considerable time spent in these institutions have generated emerging interest in these settings as an important early-life factor of PA in preschoolers [12]. Consequently, one could conclude that the preschool environment is an ideal institution for PA promotion and obesity prevention [13, 14]. However, a review by Reilly concluded that PA levels are typically very low during out-of-home care, with great variability between the settings [14].

In these settings, unstructured PA during recess and free-play times or structured PA during physical education (PE) classes provides different opportunities to achieve the necessary amount of PA. Eveline et al. [15] showed that preschool children are, on average, engaged for half of the time in sedentary behaviors even in structured PE lessons, whereas Gordon et al. [16] detected that outdoor activity and incorporated unstructured activity had a great effect on moderate to vigorous activity (MVPA). Another study suggests that preschoolers' PA could potentially be increased by shorter bouts of structured PA throughout the preschool day [17].

All these results demonstrate the complex backgrounds of PA behavior in this age group and also show that the specific reasons for low PA levels among preschoolers need to be better understood [7].

To guide the development of PA intervention in preschool settings, it is important to identify structures that promote regular PA [18]. In this context, a study of country- or region-specific preschool programs, along with an evaluation of their effects on PA, could be helpful in identifying the chances and risks associated with the promotion of PA in preschool for obesity prevention.

By comparing four cities (Freiburg and Landau in Germany, Basel in Switzerland, and Strasbourg in France) in the trinational Upper Rhine region that provide distinct programs in preschool education, we aimed at identifying the amount of PA that is potentially possible in different educational settings. Furthermore, we analyzed PA levels in the family context to see how they are mediated by both weight and selected family habits.

2. Method

2.1. Study Design. The study was conducted in the named four cities because these cities are all capital members in the trinational Upper Rhine region and had to be chosen due to political reasons. The study was financially supported by the Franco-German-Swiss Conference of the Upper Rhine that mandated an explorative evaluation study of different preschool settings and their impact on children's PA levels. Therefore, we only involved preschools in the city centers to avoid a town bias. All measurements were taken in the summer during three weeks, with no holiday days in the measurement time and almost similar weather conditions. The study was approved by the local Ethics Committee.

In the selected cities, we contacted the municipality of preschools which informed the principals of public preschools of our research interest. Interested preschools (Freiburg $n = 4$; Basel $n = 5$; Strasbourg $n = 5$; Landau $n = 3$) gave their consent to participation. Due to the explorative status of the study, neither a nonresponder analysis to identify patterns of nonparticipation nor a power calculation was conducted. Additionally, due to limited measurement devices, we randomly chose two preschools per city. During a parents' evening, we informed all parents with children aged five to six years about the aims of our research and invited them to enroll their children in the study. After parents had given their written informed consent for the participation of their child, $N = 163$ children were measured by direct accelerometry for five consecutive days: three weekdays (WD) and two weekend (WE) days. Parents' participation quota in the different preschools varied between 38% and 75%.

2.2. Measurements. Anthropometric assessment included measurement of each child's weight, height, and skinfolds. Weight status was categorized by body mass index (BMI). Children were classified as nonoverweight (<90. percentile) and overweight (>90. percentile), according to national reference BMI percentiles of German children, and the individual BMI data was converted to standard deviation scores (BMI-SDS) [19]. Skinfold thickness (SF) was determined on the right side of the body using a skinfold caliper (Lange Calipers). All measurements were done by the same investigator. To calculate the percentage body fat (%BF) from the SF, age and gender-specific regression equations were used according to Slaughter et al. [20].

By answering a questionnaire, parents provided information about their selected family markers (profession, family status, and number of children in total), their weight and height status (to calculate the BMI), their leisure time PA on weekdays and at weekends (in minutes), and their media consumption on weekdays and at weekends (in minutes). Additionally, they reported the time that their child spent in leisure time PA and screen-time entertainment (in minutes). The questionnaire used is part of the quality management of the FITOC-program (Freiburg Intervention Trial for Obese Children) and is accepted by German health insurances. Results have already been published [21].

Triaxial accelerometers (AiperMotion 440, Aipermon GmbH, Germany) were used to assess the sedentary behavior of the children, which is discussed as an independent risk factor [22]. The subjects were requested to wear the accelerometers on a belt at their hip for the whole day. Parents were asked to remove the child's accelerometer for water activities (such as swimming, taking a shower or a bath) and to refit it afterwards. They were also asked to remove it for sleeping and to refit it in the morning directly after the child got out of bed. The AiperMotion system uses 3D acceleration sensors and analyzes data with a disclosed online algorithm. The online algorithm of the AiperMotion system provides a distinction between active and passive time with a 4 s resolution, which can be used as an estimate of the time spent with and without physical activity [23]. Data from the motion sensor was exported to MATLAB (The Mathworks, USA) for further analysis. Phases without any physical activity for ≥20 min were considered as nonwear time and excluded from the calculation of the mean active time. Furthermore, days with more than 50% nonwear time in the examined period were excluded from further analysis. The ratio of active and passive time, excluding nonwear time and days with insufficient recording time, was calculated for each period (i.e., time from 9:00 a.m. to 12:00 p.m.), averaged across recording days with sufficient wear time for each subject. Subsequently, the mean activity was averaged across subjects, and the active and passive time were displayed in minutes. Although the chosen device and the measured cut points are not comparable with cut points measured by the actigraph system, the data gives reliable results within this setup.

Table 1: Timetables of preschools in the different locations.

Time	Germany (Freiburg, Landau)	Switzerland (Basel)	France (Strasbourg)
8:30–9:00	Unstructured free-play, indoor, and outdoor	Taught lesson	
9:00–9:30		Unstructured free-play, indoor, and outdoor	Taught lesson
9:30–10:00			
10:00–10:30	Breakfast	Breakfast	Breakfast
10:30–11:00	Unstructured free-play, indoor, and outdoor	Recess outdoors	Recess outdoors
11:00–11:30		Unstructured free-play, indoor, and outdoor	Taught lesson
11:30–12:00			
12:00–12:30	Sitting circle	Parents pickup	Lunch break (eating, sleeping)
12:30–1:00	Parents pickup		
1:00–1:30			
1:30–2:00			
2:00–2:30			Physical education
2:30–3:00			
3:00–3:30			Taught lesson
3:30–4:00			
4:00–4:30			Closing session (singing, unstructured play)
4:30–5:00			Parents pickup

Different schedules and curricula of the preschools in the three countries provided us with the opportunity to interpret the PA levels in the different institutions (Table 1). In France, children aged three to six years attend *l'école maternelle* in three different classes: youngest section, middle section, and oldest section. France takes seriously the education of children in their preschools as preparation for attendance at primary school. It is not "playschool"—there is a course of study that children are required to follow. The mandated curriculum leads to lessons taught during a fixed schedule for the entire preschool day (9:00 a.m.–5:00 p.m.) [24]. In Germany, different preschool programs exist (half-day or full-day). The chosen preschool settings in Freiburg and Landau provide half-day care (8:00/9:00 a.m.–1:00/2:00 p.m.), without different age classes, attended by children aged three to six years. Recommended curricula for preschools exist depending on the federal state, but only the aims of education are obligatory. Each institution is free in its creation of the schedule [25]. In Switzerland, half-day care is customary for children aged four to six years with region-specific curricula [26]. The chosen schedules in Switzerland and Germany provide high amounts of free-play time individually structured by the preschool itself. All provided timetables and further information about the playground sizes of the different institutions are presented in Tables 1 and 2.

Due to missing values in the accelerometer or questionnaire data, $N = 54$ children had to be excluded from the sample. Finally, in total $N = 114$ children (mean age = 5.3 (0.65) years) could be taken into account for the statistical analyses.

2.3. Statistical Analyses. All analyses were calculated with IBM© SPSS© Statistics Version 20. For all statistical analyses, the significance level was set at $\alpha = 0.05$.

Table 2: Indoor/outdoor facilities preschools.

Preschool	Indoor classrooms m^2	Outdoor playground m^2
Freiburg 1	48 m^2	300 m^2
Freiburg 2	45 m^2	400 m^2
Landau 1	30 m^2	50 m^2
Landau 2	20 m^2	200 m^2
Basel 1	No different classrooms, one big indoor playground 150 m^2	300 m^2
Basel 2	No different classrooms, one big indoor playground 180 m^2	300 m^2
Strasbourg 1	30 m^2	Only 30 min. recess outdoor 200 m^2
Strasbourg 2	35 m^2	Only 30 min. recess outdoor 200 m^2

Preliminary analyses consisted of descriptive statistics of the anthropometrical data and family markers in the sample. One-factor ANOVAs (with Scheffe post hoc test) were used to identify mean differences in the anthropometrical data between children from different locations. Based on the parents' self-report of whether they live in a partnership or are married or if they are the only legal guardian, we classified the families as "partnership with two parents" or as "single parent." Furthermore, we classified the families according to the number of children as "one-child families," "two children families," and "more than two children families." Self-reported height and weight were used to calculate parents'

Table 3: Distribution of the anthropometrical data and family markers in the sample differentiated by cities.

Anthropometrical data	Freiburg (D) M (SD)	Landau (D) M (SD)	Basel (CH) M (SD)	Strasbourg (F) M (SD)	Total M (SD)
Weight-SDS (in kg)	0.25 (0.80)	0.34 (0.86)	0.09 (0.99)	0.52 (1.03)	0.31 (0.94)
Height-SDS (in cm)	0.22 (0.91)	0.36 (0.83)	0.13 (0.92)	0.54 (1.35)	0.32 (1.06)
BMI-SDS	0.18 (0.85)	0.18 (0.78)	0.07 (1.02)	1.12 (1.78)*	0.46 (1.33)
%BF	18.83 (4.99)	18.66 (3.63)	17.49 (4.48)	18.99 (5.21)	18.50 (4.71)
Mother's BMI	23.95 (5.04)	22.99 (3.76)	23.46 (3.77)	23.73 (4.93)	23.59 (4.46)
Father's BMI	24.90 (2.11)	25.71 (4.05)	24.92 (3.66)	25.23 (2.78)	25.15 (3.07)
Family markers	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)
Single parent	5 (17.9)	5 (26.3)	3 (13.0)	5 (16.1)	18 (17.8)
In partnership	23 (82.1)	14 (73.7)	20 (87.0)	26 (83.9)	83 (82.2)
1-child family	4 (14.3)	6 (33.3)	3 (12.0)	6 (18.2)	19 (18.3)
2-child family	13 (46.4)	8 (44.4)	12 (48.0)	15 (45.5)	48 (46.2)
<2-child family	11 (39.3)	4 (22.2)	10 (40.0)	12 (32.4)	37 (32.5)

*$P \leq .05$.

BMI. To identify differences in these family markers, we calculated Pearson's chi-squared tests.

In analyzing our research question, one-factor ANOVAs (with Scheffe post hoc test) were conducted to examine differences between the children's PA in the four different cities, on weekdays as well as at the weekend. To compare full-day care with half-day care, we divided the data into two periods: morning (9:00 a.m.–12:00 p.m.) and afternoon (2:00–6:00 p.m.). In the time slot of the morning, we could be sure that all children attended preschool and for the afternoon we could be sure that only the French children attended preschool and all the other children did not. Due to this division, we can compare PA levels in the morning in the different institutional care settings and PA levels in the afternoon in preschool and in different family care settings.

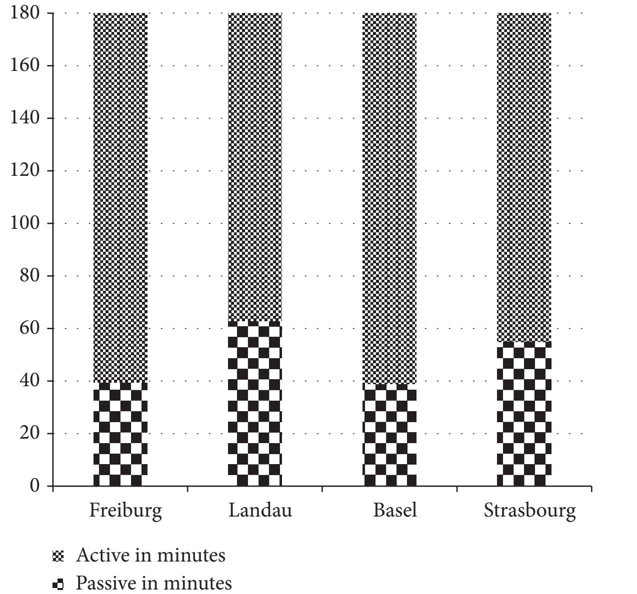
A one-factor ANOVA (with Scheffe post hoc test) was calculated to examine differences between PA on weekdays and at the weekend for the total sample. Unpaired t-tests were used to discover mean differences in PA on weekdays and at the weekend between normal weight and overweight children. For the comparisons with the weekend, we took the time slot 9:00 a.m.–6:00 p.m.

To identify the impact of family markers (family status, number of children, media consumption, and leisure time engagement in physical activity of parents and child) and parents' weight status (BMI) on preschoolers' PA levels in the afternoon on weekdays and at weekends, we calculated a multiple stepwise regression with "time spent passive" in the concerned slot as the dependent variable.

3. Results

3.1. Description of the Sample. The sample included $N = 114$ children ($n = 48$ boys and $n = 66$ girls; mean age = 5.3 (0.65) years) from different preschools in Freiburg ($n = 28$) and Landau ($n = 19$) (Germany), Basel ($n = 30$) (Switzerland), and Strasbourg ($n = 37$) (France). Table 3 presents the sample size and the descriptive statistics for the anthropometrical data (weight, height-SDS, BMI-SDS, and %BF) and the family markers (family status, number of children in family, and parents' BMI) differentiated by cities. In total, 82.1% of the children are of normal weight, and 17.9% are over the 90th percentile and therefore overweight. The research subjects in Strasbourg had a higher BMI-SDS (mean = 1.12 (1.78)) than all the other children at the three other locations ($P = .00$; $F = 5.12$; partial eta^2 = 0.12). There are no significant differences in height-SDS and weight-SDS. Considering boys and girls, there were no gender differences in the anthropometrical data, except the percentage of body fat ($t = 8.48$; (df: 111); $P = .00$; $d = 0.63$). For mothers' and fathers' BMI, there are no significant differences between the four cities. There is no significant distribution effect for the four cities concerning family status and the number of children in the family. We also cannot state a distribution effect of overweight and normal weight children on the different family status. Even if Pearson's chi-squared test missed the set significance with $P = .08$, we would like to report that overweight children are more often found in one-child families.

3.2. PA in the Forenoon on Weekdays (9:00 a.m.–12:00 p.m.) Differentiated by Cities. In the morning from 9:00 a.m. to 12:00 p.m., all of the children in the study attend preschool. Therefore, it is possible to compare how much PA the different educational systems allow in their schedules. Freiburg and Landau plan 150 minutes of unstructured play, Basel 120 minutes, and Strasbourg 30 minutes (in the form of an outdoor recess). A one-factor ANOVA showed high significant mean differences ($P = .00$; $F = 13.01$; partial eta^2 = 0.29) between the different locations in average PA time. Scheffe's procedure shows that children in Strasbourg and Landau are significantly more passive in the morning than children in Freiburg and Basel (Figure 1). However, comparing the groups concerning their planned unstructured free-play times, we can see that children in Strasbourg are more active than in the 30-minute planned free-play time, whereas children in Landau are less active than the planned 150 minutes of unstructured free-play time.



City	Active in minutes (SD; R)	Passive in minutes (SD; R)
Freiburg	140.62 (25.20; 103.00)	39.38 (14.58; 57.00)
Landau	117.24 (22.57; 85.50)	62.76 (22.57; 85.50)
Basel	141.22 (8.00; 31.00)	38.78 (8.00; 31.00)
Strasbourg	125.1 (16.45; 69.3)	54.9 (16.45; 69.3)

Figure 1: PA in the morning on weekdays (9:00 a.m.–12:00 p.m.) differentiated by countries and cities.

3.3. PA in the Afternoon on Weekdays (2:00–6:00 p.m.) Differentiated by Cities and Family Markers. In the afternoon from 2:00 to 6:00 p.m., the studied children in Strasbourg attend preschool, whereas child care in Freiburg, Landau, and Basel is the responsibility of the family. A one-factor ANOVA did not show any significant mean differences in PA time between the children at the different locations. Scheffe's procedure did not show any significance between the groups either. To analyze the impact of different family markers (family status, number of children in the family, engagement in leisure time PA of parents and child on weekdays in minutes, media consumption of parents and child in minutes, parents' BMI, and child's BMI-SDS), we calculated a multiple stepwise regression without the French children because they are not cared for in the family context in the afternoon. The analysis showed that only the predictor "number of children in the family" has an impact on children's PA level (P = .04; r^2 = .11; F = 4.63; β = .33): the more siblings a child has, the more active a child is in the afternoon.

3.4. PA at Weekends (9:00 a.m.–6:00 p.m.) Differentiated by Cities and Family Markers. Child care at the weekend is entirely the responsibility of the family. On the one hand we tested whether there were differences in PA time between the different locations, and on the other hand we tested in an explorative way whether different family markers influence preschool children's PA level at weekends. A one-factor ANOVA for the different locations identified no significant differences in mean PA time among the children at weekends. A multiple stepwise regression showed that children's PA level at weekends is predicted by the child's BMI-SDS (β = .38; P = .01) and the mother's BMI (β = .32; P = .02) (P = .04; r^2 = .23; F = 5.92; P = .00).

3.5. PA and Weight Status. To test mean differences in PA of different weight categories, we calculated an unpaired t-test with all normal weight and overweight children, independent of location. Overweight children are significantly more passive on weekdays as well as at weekends (for weekdays: t = −2.89; (df: 97); P = .044; d = .21; for weekends: t = −2.14; (df: 91); P = .018; d = .29). For weekdays, a multiple stepwise regression did not provide predictors of the different PA levels of overweight and normal weight children. For the weekends, as already shown above, the child's BMI-SDS in combination with the mother's BMI is a predictor of the child's PA level at weekends.

4. Discussion

We found a higher percentage of overweight children in this age group, independent of location, compared to the representative German [27], Swiss [28], and French [29] reference data, but the prevalence is comparable to US data [30]. Comparing the four locations, the children in Strasbourg (France) showed a significantly higher BMI-SDS score. Our results support the literature that argues that the increasing prevalence of childhood obesity is one of the central public health challenges in modern societies [1, 31]. Evaluating PA between the weight categories, our data demonstrates a significant difference between normal weight and overweight preschoolers. Overweight children are significantly more passive on weekdays as well as at weekends. Literature provides evidence that normal weight children spend more time on average in PA than overweight children [32, 33], but there are only a few studies showing this difference in this early-age group.

As the nature of preschool has changed towards incorporating the educational domain into child care, preschool has the increasing function of teaching basic literacy and numeracy, with the aim of preparing children for school; as a result, desk-based instruction has become more important in preschools [14, 33]. With regard to the PA level, our study demonstrates that, by comparing open versus desk-based programs in the three countries, the regimented and highly structured French system leads to more inactivity in preschoolers compared to the more unstructured system in Switzerland and in Freiburg (Germany) in the morning. Desk-based care might offer fewer possibilities of PA time. Nevertheless, the French children are more active than the planned activity time in schedules. This means that the investigated French preschools probably integrate activity in their teaching.

Furthermore, the results of the second German city, Landau, show that open-orientated programs do not promote PA per se. Although the Landau and Freiburg timetables allow the same amount of free-playing time, the activity levels of children are different. It seems that open settings have to provide special structures to promote PA. Critical factors could be the number and formation of caregivers and their own engagement or training in PA. Additionally, portable equipment and larger playgrounds are associated with higher activity levels in preschoolers [34, 35]. Investigating differences in the free-play periods in Germany and Switzerland, we analyzed indoor areas, playgrounds, and outdoor possibilities and found more outdoor possibilities, as well as larger indoor areas and playgrounds in Basel and Freiburg than in Landau and Strasbourg (Table 2). With regard to the importance of indoor/outdoor play to enhance PA, the literature provides controversial results [36, 37], but Olesen et al. identified a positive association between MVPA during preschool attendance and the size of indoor area per child [38].

By collecting different family markers such as family status, number of children in the family, engagement in leisure time PA, and screen-time behavior, as well as parents' anthropometrical data, we tried to analyze in an explorative way the influence of these markers on preschool children's PA levels. For the family care in the afternoon on weekdays, we have seen that only the number of children in a family predicts the child's PA level. So, we are able to differentiate the research on families with young children as being potential risk groups. Due to our data, families with more than one (young) child seem to provide more PA than families with only one young child. These results find support in a study by McMinn et al., showing that the number of siblings, family encouragement, and family social support are associated with higher PA levels in children [39]. Our result can also be seen as important in the context of the tendency for more overweight children to come from one-child families that our data could not prove with significance, probably due to few cases in the single categories. Additionally, the multiple regression model showed that children's PA level at weekends is predicted by the child's BMI-SDS and the mother's BMI, so the more passive time spent by overweight children at weekends can be explained by their anthropometrical status. A recent study from Hesketh et al. [40] showed that PA levels in mothers and their preschool children are directly associated. They concluded that interventions targeted at mothers of young children may increase both groups' activity.

5. Strengths and Limitations

Measuring PA in preschoolers is difficult due to the spontaneous and irregular type of activity in this age group. However, accelerometry is the most commonly used method for this population, but since at present the literature provides no agreement in the cut point definition for thresholds for different activity levels, the present study has the bias of not measuring with the commonly used actigraph system; so, the measured cut points are not comparable with actigraph cut points. Nevertheless, the data gives reliable results and can therefore be used to compare the different locations within this setup.

In contrast to other studies that measure PA only quantitatively or only by self-report, this study combines PA measured by objective accelerometry with the timetables of preschools and questionnaires completed by parents who gave additional information about different family markers that might influence the preschooler's PA level. Therefore, this study shows in an explorative way the effects of different preschool settings on the PA level in the forenoon of weekdays as well as the importance of the number of children in a family for the PA level on weekdays in the afternoon, as well as of the mother's and child's anthropometrical status for the child's PA level at weekends.

In addition, the presented data is limited due to several reasons. Firstly, we had only two study preschools per city. Even if we chose by random the preschools interested in the study, we would have had a selection bias. Secondly, in the studied preschools, we had to take a selection bias into account as well, because only those children whose parents were interested in the study and gave their written consent participated in the study. Thirdly, the data set only includes $N = 114$ children, so the results must be seen as explorative results.

6. Conclusion

This study highlights the increasing prevalence of overweight in the preschoolers age group and the influence of multidimensional early-life factors on PA. Taking into account the high percentage of children attending a preschool, one could suggest that preschools might be a suitable setting for establishing active lifestyle habits, thereby preventing obesity. Our study has shown that "open concept" child care programs that typically feature the most free-play time seem not to promote PA per se in contrast to more desk-based programs. Therefore, preliminaries such as the special training of caregivers as well as sufficient equipment, playground size, and number of caregivers are necessary.

With regard to family context as an important early-life factor, a higher number of children in a family and the mother's and child's anthropometrical status are predictors of the engagement in PA. Further investigations into these family contexts and targeted interventions for special groups should be more focused in the future.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Research Article

Malnutrition, Overweight, and Obesity among Urban and Rural Children in North of West Azerbijan, Iran

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Introduction. Malnutrition is one of the most important causes for improper physical and mental development of children. Childhood obesity is a worldwide public health problem. The increasing prevalence of childhood obesity has become a growing matter of public health concern worldwide. The aim of the current study was to determine the prevalence of malnutrition and obesity in children under 5 years old in Salmas district. *Methods.* The current study is a cross-sectional study conducted on 902 of children under 5 years old to assess the nutritional status in Salmas district and performed from 16 until 30 October, 2011, with the cooperation of the Office of Community Nutrition Improvement and the United Nations Children's Fund. ENA (Emergency Nutrition Assessment) and Spss software were used for data analysis. *Results.* 49.6% of children were boys and 50.4% were girls. The prevalence of malnutrition based on underweight, stunting, and wasting was estimated to be 2.3%, 7.3%, and 1.4% among children, respectively. Stunting was more common in rural areas and this difference was significant ($P < 0.001$). *Conclusion.* In this area stunting, overweight and obesity were the most important priorities that health officials must pay more attention to. ENA software has a special ability to determine the samples and clusters and is a simple, rapid, and accurate method, especially in epidemiological studies in the country, and can be a convenient tool and its use is suggested for the same studies.

1. Introduction

Malnutrition is one of the most important causes for improper physical and mental development of children [1]. One in every five children in the developing world is malnourished, and poor nutrition is associated with half of all child deaths worldwide [2]. Malnutrition in children causes an increase in morbidity and mortality and has an adverse effect on intellectual ability [3]. Globally, acute malnutrition causes more than 50% of childhood mortality in children under 5 years old, which implies that about 3.5 million children die of malnutrition each year [4].

Malnutrition measures in many ways. Clinical grading standard, weight-for-height (WFH) index (Figure 1), height-for-age (HFA) index, weight-for-age (WFA) index (Figure 2), body mass index, and skin fold thickness are to be used more frequently in the field [5]. In April 2006, the WHO released new global growth charts for infants and children as old as 5 years to replace the existing CDC/WHO international growth charts, which were based on the 1977 NCHS growth charts [6].

The worldwide malnutrition estimation rates indicate that 35.8% of preschool children in developing countries are underweight, 42.7% are stunted, and 9.2% are wasted [7]. Childhood obesity is a worldwide public health problem [8]. The increasing prevalence of childhood obesity has become a growing matter of public health concern worldwide. Obesity has increased from 4.2%, in 1990, to 6.7%, in 2010, worldwide and is expected to reach 9.1%, in 2020 [9, 10].

In Iran, like many of the other developing countries, the prevalence of obesity in children has been moving on [11]. According to a survey in West Azerbaijan, 8.7%, 7.5%, and 4.3% of the children aged less than five years suffered from stunting, wasting, and underweight, respectively [12].

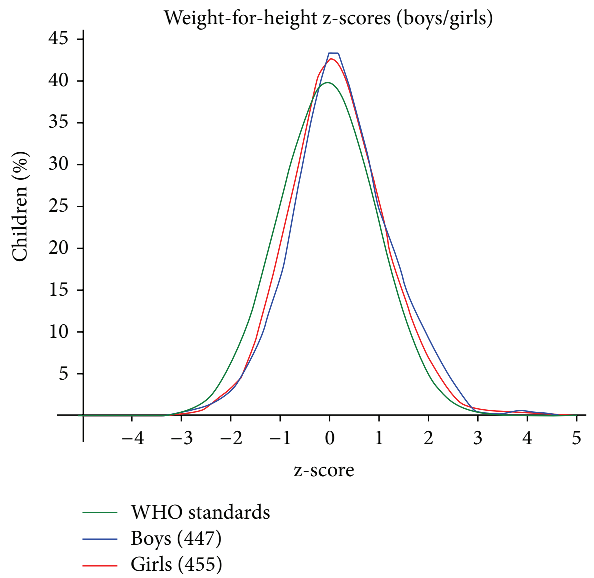

Figure 1: The graph of the normal distribution of weight for height in studied children in Salmas (mean ± SD = 0.21 ± 0.94).

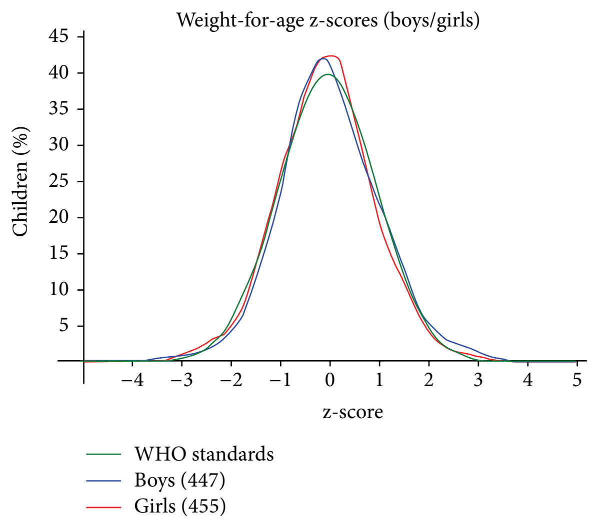

Figure 2: The graph of the normal distribution of weight for age in studied children in Salmas (mean ± SD = −0.01 ± 0.96).

The present study aimed at assessing the prevalence of malnutrition (underweight, stunting, wasting, overweight, and obesity) in under-five-year-old children in Salmas district.

2. Methods

The current study is a cross-sectional study which was conducted for assessing the nutritional status of children under 5 years old in Salmas district on the basis of national guide and has been performed from 16 until 30 October, 2011, with the cooperation of the Office of Community Nutrition Improvement and the United Nations Children's Fund (UNICEF). Using cluster sampling, the statistical population included 0–59-month-old children residing in the cities and villages of Salmas and by ENA software sample size was calculated with 5% confidence interval; 902 children were determined. In this study, children being mentally and physically retarded and having problems in terms of anthropometry were removed from the study and replaced by other children. The Institutional Review Board approved this study. For medical ethics, the parental consent form must be completed to conduct completed design. In this study, cluster sampling is used for selecting the samples. For this purpose, first, the total number of households residing in rural and urban areas and the total number of children between 0–59 months in Salmas city were cumulatively calculated. Then, in the ENA software items, in the planning part, the desired items were entered into sample size calculation as follows:

the number of children under 5 years old: 19824 people,

estimate of the prevalence number of malnutrition: 8.7,

widespread confidence interval: 2.3,

design effect: 1.5.

After entering the above information, 841 were determined as the sample size and, with 5% confidence interval for a sample sufficiency, the number of children was calculated as 885 children and, finally, in the study, 902 questionnaires were completed. Given that it was supposed to study 18 children in each cluster, 50 clusters were determined for this study. Then, the ratio of urban and rural populations in Salmas was calculated in this region; the urban population was 49% and the rural population was 51%. Therefore, 26 rural clusters and 24 urban clusters were determined and in the next stage the names of all villages and urban blocks were separately entered into the part of selecting clusters in ENA software according to the number of clusters. The required data were collected through measuring the height and weight and arm circumference of the children in the study, completing the questionnaire and interviews with mothers or caregivers of children. The scale used in this study was a single pan balance with the maximum capacity of 150 kg and accuracy of 100 gr. If possible, the child was directly weighed. If the baby was too small or cried so hard, first, the mother was weighed alone and then hugged the child. The scale automatically calculated the weight of the child by subtracting. Also, every day before starting work, to ensure the accuracy of the scale, the scale was tested using the control scale. The height measuring board was also used to measure height. The height of less-than-two-year children was measured in a supine and larger children were measured in standing position with an accuracy of one tenth of millimeter. The height measuring board was used for both positions. The middle of the left arm circumference in children from 6 to 59 months was measured using a special band of measuring arm circumference based on the following steps and was recorded in millimeters. Chi-square test was to be used for relationship independent variables (sex and region) with malnutrition.

3. Results

This study was done on 902 children under 5 years old including 49.6% being boys and 50.4% being girls. Most children were in the age group of 18–29 months (24.7%) and the lowest number was in the age group of 54–59 months (8.8%) (Table 1). Totally, the prevalence of malnutrition based on underweight, stunting, and wasting was estimated to be 2.3%, 7.3%, and 1.4% among children, respectively.

The results of the study showed that underweight in girls and rural areas was more common. Malnutrition under height for age in girls and boys in rural areas was more than that of the urban areas; also, we found that wasting index was not different in both sex and area. Stunting was more common than the other two malnutrition indexes (Table 2). Current study showed that prevalence of overweight and obesity in girls and rural areas was less than in boys and urban areas but this difference was not significant (Table 3). The relationship between gender and region with malnutrition showed that there was no statistical difference between sex and underweight, wasting, and stunting, but stunting was more common in rural areas and this different was significant ($P < 0.001$) (Table 4). The graph of the normal distribution of height for age in studied children in Salmas shows that distribution of height for age was skewed to left comparing with WHO standard (Figure 3).

Table 1: Characterize of children 6–59 months in Salmas 2011.

Age (month)	Boy (%)	Girl (%)	Total (%)
6–17 months	78 (45.6)	93 (54.4)	171 (19)
18–29 months	109 (48.9)	114 (51.1)	223 (24.7)
30–41 months	114 (53.3)	100 (46.7)	214 (23.7)
42–53 months	105 (48.8)	110 (51.2)	215 (23.8)
54–59 months	41 (51.9)	38 (48.1)	79 (8.8)
Total	447 (49.6)	455 (50.4)	902 (100)

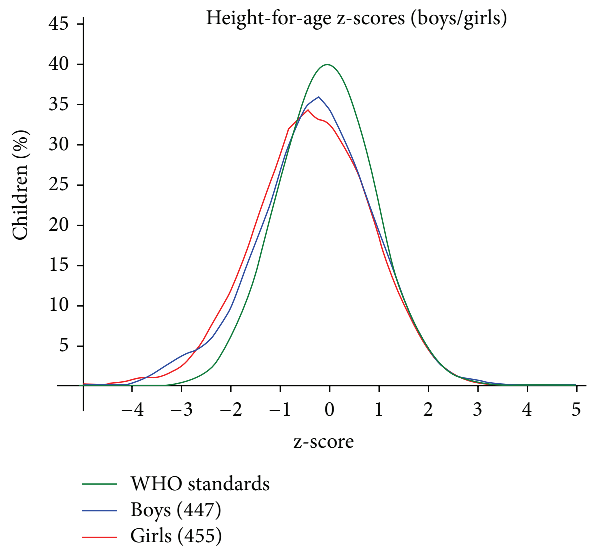

Figure 3: The graph of the normal distribution of height for age in studied children in Salmas (mean ± SD = −0.28 ± 1.08).

4. Discussion

The aim of the current study was to assess the nutritional status of under-five-year-old children in urban and rural areas in Salmas district. The prevalence of malnutrition based on underweight, stunting, and wasting was estimated to be 2.3%, 7.3%, and 1.4% among children, respectively, in Salmas district. In a study in West Azerbaijan province by Farrokh-Eslamlou, prevalence of underweight, stunting, and wasting was estimated to be 4.3%, 8.7%, and 7.5%, respectively [12]. In another study, by Veghari, malnutrition was observed in 3.20%, 4.93%, and 5.13% based on underweight, stunting, and wasting, respectively [13]. In another study in Khorasan province Northeast of Iran the rate of underweight, stunting, and wasting was reported to be 7.5%, 12.5%, and 4.4%, respectively [7]. According to the UNICEF report, 11%, 15%, and 5% of under-five-year-old Iranian children suffer from underweight, stunting, and wasting up, respectively [13]. Results of current study showed that underweight in girls and rural areas was common more which is consistent with other studies [7, 13]. Malnutrition based on height for age in both girls and boys in rural areas was more than urban areas which is due to the poor economic status, cultural status, income level, food behavior, and less health care in rural areas that are known as the risk factor for malnutrition. Our findings show that there was no statistical difference between sex and underweight, wasting, and stunting, but we found statistically significant differences between stunting and region where stunting was more common in rural areas which is consistent with previous studies in Iran [12] and stunting is still highly prevalent in underdeveloped and developing countries [14].

In current study, prevalence of obesity and overweight in children was 1.3% and 5.1%, respectively. The prevalence of overweight and obesity is increasing worldwide and has become a public health challenge [10, 15]. The tracking of childhood overweight and associated health consequences into adulthood is of concern; several serious physical conditions are associated with overweight, especially obesity, among children including asthma, sleep problems, cardiovascular diseases, and type 2 diabetes. Prevalence of obesity and overweight in boys and urban areas was more than girls and rural areas but this difference was not significant.

5. Conclusion

In this area, stunting, overweight, and obesity are the most important priorities that health officials must pay more attention to. Given the differences between various provinces and regions of the country which are a result of the differences between the levels of development in these areas, the necessity of designing and implementing targeted strategies are required for different areas. It is worth noting that the present study has been conducted in a single period and in only one city of each province and using ENA software; therefore, the judgment about the whole province requires general investigation in all cites of the province and the

Table 2: The distribution of nutritional status (underweight, stunting, and wasting) in children in Salmas.

Index	Area				Total
	Urban		Rural		
	Boy $N = 225$ (%)	Girl $N = 207$ (%)	Boy $N = 222$ (%)	Girl $N = 248$ (%)	$N = 902$ (%)
Underweight (< −2 z-score)	5 (2.2)	2 (1)	3 (1.4)	11 (4.4)	21 (9)
Moderate underweight (< −2 z-score and ≥ −3 z-score)	4 (1.8)	2 (1)	2 (0.9)	11 (4.4)	19 (8.1)
Severe underweight (< −3 z-score)	1 (0.4)	0 (0)	1 (0.5)	0 (0)	2 (0.9)
Stunting (< −2 z-score)	9 (4)	8 (3.9)	22 (9.9)	27 (10.9)	66 (28.7)
Moderate stunting (< −2 z-score and ≥ −3 z-score)	5 (2.2)	7 (3.4)	19 (8.6)	22 (8.9)	53 (23.1)
Severe stunting (< −3 z-score)	2 (1.8)	1 (0.5)	1 (1.4)	5 (2)	9 (5.7)
Wasting (< −2 z-score)	4 (1.8)	3 (1.4)	3 (1.4)	3 (1.2)	13 (5.8)
Moderate wasting (< −2 z-score and ≥ −3 z-score)	4 (1.8)	3 (1.4)	2 (0.9)	2 (0.8)	11 (4.9)
Sever wasting (< −3 z-score)	0 (0)	0 (0)	1 (0.5)	1 (0.4)	2 (0.9)

Table 3: The distribution of BMI in sex and area.

BMI	Gender		Area	
	Boy $N = 447$ (%)	Girl $N = 455$ (%)	Urban $N = 432$ (%)	Rural $N = 470$ (%)
Normal (<2 z-score)	418 (93.5)	438 (96.2)	402 (93.1)	454 (96.7)
Overweight (≥2 z-score and ≤3 z-score)	22 (4.9)	14 (3.1)	23 (5.3)	13 (2.7)
Obesity (≥3 z-score)	7 (1.6)	3 (0.7)	7 (1.6)	3 (0.6)
P value*	0.3		0.2	

*Chi-square test.

Table 4: Comparison of status and proportion of malnourished children by gender and region in Salmas.

Variable	Weight for age		Height for age		Weight for height	
	Normal (%)	Malnourished (%)	Normal (%)	Malnourished (%)	Normal (%)	Malnourished (%)
Gender						
Girl	442 (97.1)	13 (2.9)	420 (92.3)	35 (7.7)	449 (98.7)	6 (1.3)
Boy	439 (98.20)	8 (1.8)	416 (93.1)	31 (6.9)	440 (98.4)	7 (1.6)
P value	**0.29**		**0.66**		**0.75**	
Area						
Urban	426 (98.4)	7 (1.6)	416 (96.1)	17 (3.9)	426 (98.4)	7 (1.6)
Rural	455 (97)	14 (3)	429 (89.6)	49 (10.4)	463 (98.7)	6 (1.3)
P value*	**0.17**		<**0.001**		**0.67**	

*Chi-square test.

obtained results are solely applied to these three cities. This study, also, showed that the ENA software has a special ability to determine the samples and clusters and is a simple, rapid, and accurate method, especially in epidemiological studies compared to other methods that were used in studies in our country which can be a convenient tool and its use is suggested for the same studies. Also, the quality control of the performed activities by the teams in the field is another distinctive feature of this software which is considered of high importance and emphasizes the use of this software.

Conflict of Interests

The authors certify that there is no conflict of interests with any financial organization regarding the material discussed in the paper.

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