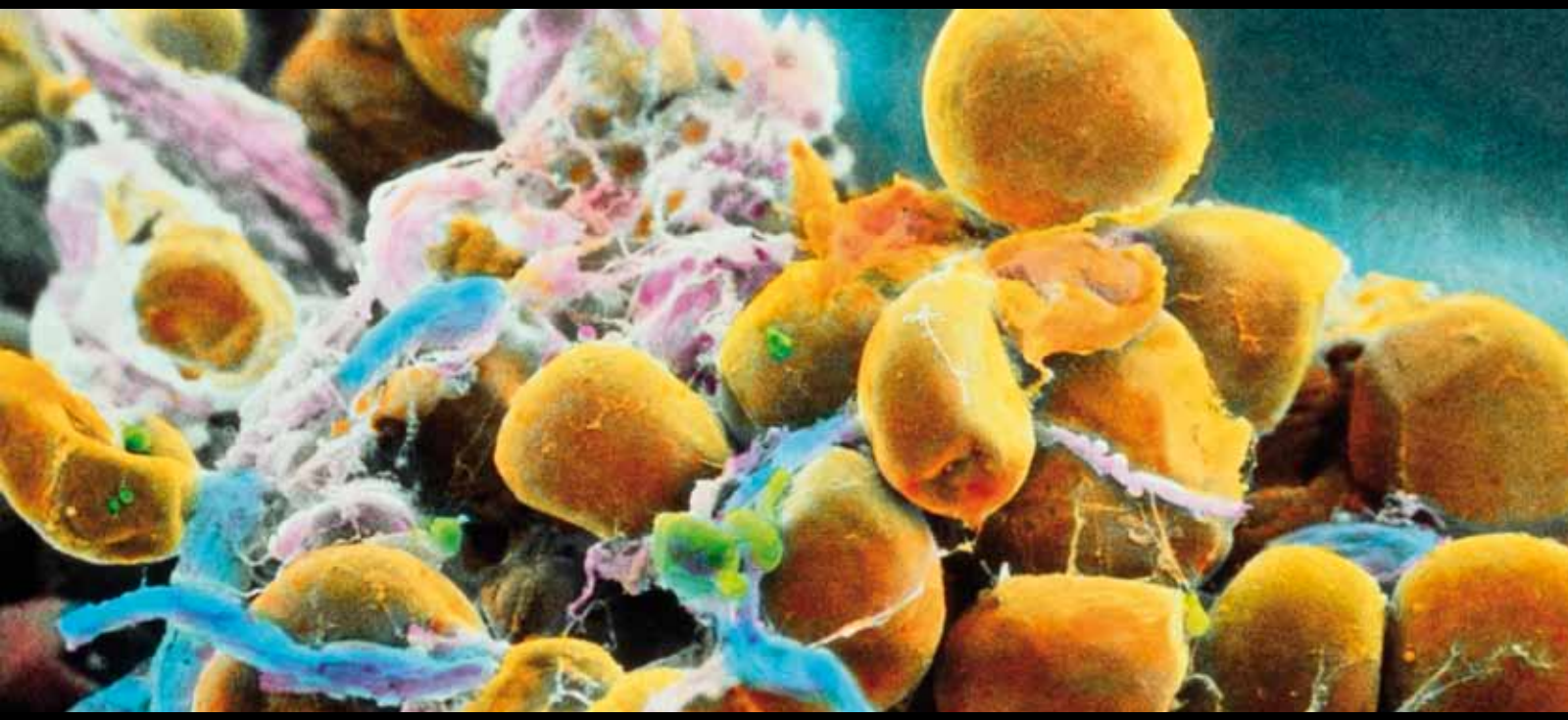
Journal of Obesity

Interdisciplinary Aspects of Childhood Obesity and Physical Fitness

Guest Editors: Jana Pařízková, Francoise Rovillé-Sausse, Charles M. Tipton, and Denes Molnár



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Editorial Board

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Editorial

Interdisciplinary Aspects of Childhood Obesity and Physical Fitness

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During recent years, the increasing prevalence of obesity has manifested in earlier periods of growth, which results in much greater health risks in later life [1, 2]. Moreover, this problem has been arising in an increasing number of countries including those which are in economic transition or are in certain social strata in developing countries which have been introducing a typical way of life in industrially developed countries, that is, reduced physical activity and inadequate dietary intake, for all age categories all round the world [1]. However, this is riskier for growing subjects, especially during certain critical periods of development, when the consequences of the adaptation to undesirable life conditions can have much more negative consequences than during later life [3, 4].

Recent comparative studies during growth revealed not only increasing adiposity [5] in the general population but also a reduction of the physical fitness level in preschool [6] and adolescent school children [7, 8], which appeared along with increasing prevalence of overweight and obesity [1]. This is related to a prevailing reduction of physical activity and exercise. Psychologists comment that "a child can learn to learn, or learn *not* to learn"; it may be added that "a child can learn to move, or to learn *not* to move." Early adaptation to increased physical activity can have a significant impact not only in the present health condition but especially in relationship to delayed consequences concerning physical fitness in later life [2, 9, 10]. The optimal level is a desirable component of health status, which should mean not only the absence of diseases but the state of full physical, mental, and social well-being [1].

To have significant results due to the adaptation to work load and exercise, a certain character, intensity, duration, and frequency of variables have to be applied. When this is not adhered to, the results might not appear or be minimal—also with regard to adiposity and physical fitness level [3, 4, 9]. Mentioned characteristics of exercise have not always been available in studies that followed scientific protocols, and conclusions of an insignificant impact from physical activity and exercise in the prevention and thus the treatment of the obese have sometimes been lacking.

Increasing experimental data concerning physical fitness and performance of the obese—especially in younger children—have been available more recently [3, 4]. It has been always difficult to assemble a group of obese children and/or adolescents sufficiently homogenous with regard to age, sex, and also duration and degree of obesity, comparable level of sexual development (which can also significantly change adiposity), and conduct adequate tests for physical fitness level. Many studies revealed reduced physical activity of obese children and adolescents, which could be a primary reason of excess adiposity, but also a consequence of it [3, 4, 7, 8].

Tread-mill, bicycle ergometer testing, and so forth have been always straining and unpleasant for the obese, and those without health complications are difficult to get in sufficient numbers. Generally, cardiorespiratory efficiency during transferring one's own body weight along a distance is mostly tackled by overweight and obesity [4]. Previous measurements revealed, nevertheless, sometimes quite high absolute values, for example, of oxygen uptake during maximal work loads [11]. However, when related to total measurements

and especially lean body weight, mostly reduced values were found [4, 10, 12]. Moreover, a certain level of the maximal oxygen consumption during tread-mill or bicycle tests was achieved after a shorter testing periods. Obese subjects had to finish the dynamic work load earlier than normal weight subjects; that is, their ability to achieve maximal performance with the same oxygen uptake was significantly reduced [4]. After the reduction of treatment by exercise, along with the reduction of fat and BMI, the cardiorespiratory efficiency was also significantly increased and higher performance was achieved; that is, subjects were able to run for a longer time, with higher speed, and so forth than before treatment [10, 12]. But it should be mentioned that the ability of smaller muscle groups can be unchanged by obesity, and muscle strength is even increased due to enhanced development of lean (mostly muscle) body mass, especially in subjects with longer lasting excess adiposity development [4, 10].

The positive role of physical activity on obesity prevention and treatment has been previously revealed, but indispensably under conditions of a particular character (preferably aerobic, dynamic), intensity, duration, and frequency of exercise on fitness development, [4, 12]. Present life styles especially in larger urban agglomeration, leisure time activities, mainly sedentary, but very attractive (TV, video, etc.), have been the greatest problem. To realize a recommended regime of physical activity [13] has become difficult, usually nearly impossible (safety reasons, reduced availability of supervised areas for play, etc.). Support and promotion of such regimes require increased cooperation of pedagogic, communal, political institutions, and so forth [13, 14]. Simultaneously, this also concerns a significant promotion of adequate nutrition, which has been negatively influenced by the global marketing and advertisement of undesirable industrialized foods and beverages resulting in unhealthy food habits and dietary intake, moreover in disproportion to present needs and energy output. Therefore, not only educational and pedagogic impacts are needed starting with early childhood [14], resulting in optimal physical activity habits and fitness, but also environmental and social influences favouring desirable lifestyles must be promoted as well. This requires additional and enhanced effort to include innovative intervention programs with support and cooperation of governmental, educational, social institutions, and so forth. Without well-concerted and complex endeavor, it would be difficult to achieve efficient obesity prevention and treatment *using natural and physiological factors like physical activity and fitness development*, and not pharmacological, or gastric binding and so forth, approaches, which are also more costly. The presented issue should at least partly contribute to that.

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Research Article

Effects of Adiposity and Prader-Willi Syndrome on Postexercise Heart Rate Recovery

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Heart rate recovery (HRR) is an indicator of all-cause mortality in children and adults. We aimed to determine the effect of adiposity and Prader-Willi Syndrome (PWS), a congenital form of obesity, on HRR. Sixteen children of normal weight (NW = body fat % ≤85th percentile, 9.4 ± 1.1 y), 18 children with obesity (OB = body fat % >95th percentile, 9.3 ± 1.1 y), and 11 PWS youth (regardless of body fat %; 11.4 ± 2.5 y) completed peak and submaximal bike tests on separate visits. HRR was recorded one minute following peak and submaximal exercises. All groups displayed similar HRR from peak exercise, while NW (54 ± 16 beats) and OB (50 ± 12 beats) exhibited a significantly faster HRR from submaximal exercise than PWS (37 ± 14 beats). These data suggest that excess adiposity does not influence HRR in children, but other factors such as low cardiovascular fitness and/or autonomic dysfunction might be more influential.

1. Introduction

Heart rate recovery (HRR) is the rate at which heart rate declines from the end of exercise to a predetermined time point during recovery, typically one minute after exercise [1, 2]. HRR depends on an immediate parasympathetic nervous system reactivation followed by sympathetic activity withdrawal [3]. After submaximal exercise, the withdrawal from sympathetic activity typically takes place 30 seconds into recovery [2, 4]. In contrast, increased sympathetic activity following peak intensity exercise may continue for approximately one to three minutes, delaying HRR [2, 5, 6]. A slower HRR has been related with lower cardiovascular fitness, thereby indicating an increased risk of cardiovascular disease [7]. Therefore, HRR has been suggested as a noninvasive method for cardiovascular risk assessment in both children and adults [3, 8].

Body fat is positively associated with risk for cardiovascular disease in children [9] and adults [10]. As HRR is an indirect measure of cardiovascular disease risk, studies in adults have shown that indices of obesity are strong predictors of HRR following exercise [3, 11]. Dimkpa and Oji showed that in healthy adults, obesity surrogates negatively correlated with HRR following submaximal intensity exercise [11]. Similarly, Singh and colleagues demonstrated that overweight youth experienced a slower one-minute postexercise HRR than healthy weight youth after a maximal protocol followed by one-minute cool-down period [8]. Moreover, Dangardt and colleagues suggested that children with obesity displayed a significantly lower vagal activity at rest compared to overweight and lean controls [12]. Though these studies related body fat and HRR, no research has investigated HRR from aerobic exercise in children with excessive adiposity (i.e., those classified as obese, not overweight) compared to lean controls.

In addition, measuring HRR in children predisposed to excessive adiposity (e.g., individuals with Prader-Willi Syndrome) can also reveal particular mechanisms that affect postexercise HRR response. Prader-Willi Syndrome (PWS) is the best characterized genetic cause of childhood obesity [13]. PWS is characterized by hypotonia, hyperphagia, abnormally high adiposity, hypogonadism, and lack of normal growth

hormone production [14]. Past work investigating autonomic nervous system (ANS) function in youth with PWS presents equivocal results [15–18]; therefore, those with PWS are a particularly unique comparison group to nonsyndromal children as HRR may be related to congenital adiposity and/or syndrome-related ANS dysfunction.

Stinted HRR immediately following peak exercise reveals deficits in parasympathetic reactivation [2, 5, 6], while stinted HRR from submaximal exercise reveals deficiencies in either parasympathetic reactivation or sympathetic withdrawal [2, 4]. Thus, studying HRR response from peak and submaximal exercise provides information about different ANS regulatory mechanisms. This study investigated whether adiposity and PWS influenced postexercise HRR from two different exercise intensities.

2. Methods

2.1. Participants. Sixteen (7 M and 9 F) children of normal weight (NW = body fat percentage ≤85th percentile for age and sex; BMI z-score: −0.1 ± 0.6; age: 9.4 ± 1.1 y), 18 (12 M and 6 F) children with obesity (OB = body fat percentage >95th percentile for age and sex; BMI z-score: 2.0 ± 0.5; age: 9.3 ± 1.1 y) [19], and 11 (8 M and 3 F) youth diagnosed with PWS (BMI z-score: 1.7 ± 0.7; age: 11.4 ± 2.5 y) participated in this study. This study was approved by the Institutional Review Boards from California State University, Fullerton, Children's Hospital of Orange County, and the United States Army Medical Research and Materiel Command. Written informed assent and consent were obtained from all participants and parents prior to participation. Children with diabetes mellitus type 2, confirmed pregnancy, or those unable to participate in moderate to vigorous physical activity were excluded from participation.

2.2. Experimental Design. Participants completed two visits separated by two to 14 days. During visit one, all participants were measured for anthropometrics, body composition, resting heart rate (HR), and blood pressure (BP); subjects then completed a graded exercise test. During visit two, participants performed a discontinuous submaximal test. Participants were instructed not to engage in physical activity (i.e., sports games, bike rides, physical education, etc.) for a minimum of 24 hours before exercise testing. In addition, participants were provided with a standardized breakfast that contained no caffeine to consume two hours prior to visit arrival. This study was part of a larger research effort devoted to examining the physiological and hormonal responses to exercise in youth with PWS.

2.3. Visit One

2.3.1. Medical Screening. Parents of participants completed a medical history questionnaire regarding their child's health and participation in moderate to vigorous physical activity. Children without PWS completed the Pubertal Developmental Scale [20] to assess pubertal status. PWS youth underwent a full health screening by a physician to determine contraindications for exercise testing and participation in the study, as well as Tanner stage determined by breast, genital, and pubic hair development.

2.3.2. Anthropometric and Physiologic Measurements. Participants removed shoes before all measurements. Body mass was measured using a digital scale (ES200L, Ohaus, Pinewood, NJ) while participants wore a t-shirt and shorts. Height was measured after participants inhaled using a wall-mounted stadiometer (Seca, ON, Canada). Waist circumference was measured following NHANES guidelines at the top of the participant's iliac crest at the end of exhalation [21]. Total body fat percentage was determined using a whole body dual energy X-ray absorptiometry (DXA) scan (GE Healthcare, GE Lunar Corp., Madison, WI). Female participants who had their first menses were required to complete a pregnancy test prior to completing the DXA scan. Resting HR, measured via telemetry (Polar USA, Lake Success, NY), and resting BP, measured via aneroid sphygmomanometer (Diagnostix 752, American Diagnostic Corporation, Hauppage, NY), were recorded following five minutes of seated rest [22].

2.3.3. Peak Graded Exercise Test. Participants completed the McMaster protocol, a cycling protocol tailored to height and sex [23], on a cycle ergometer (Corival Pediatric, Lode B.V., the Netherlands; Technogym Bike Med, Technogym USA Corp., Seattle, WA) suited to the child's stature. The test consisted of two-minute stages at incremental workloads until the participant reached volitional exhaustion, failed to sustain the desired workload [24], requested to stop, stood up on the bike pedals, or experienced fatigue-related symptoms [25].

Relative peak power output was computed by dividing the test termination load by the participant's lean body mass obtained from the DXA scan. BP was measured at rest and the end of exercise. HR was recorded at test termination and one minute following exercise. HRR was determined by computing a HRR value (HRRV) calculated as the difference between test termination HR and HR recorded after one minute after exercise [1]. One-minute postexercise HRR is the most commonly used methodology to assess recovery heart rate in children [1–3, 6, 8].

2.4. Visit Two. Participants completed a discontinuous submaximal test consisting of ten two-minute cycling intervals each separated by one minute of rest. The resistance setting was based on the HR obtained during the McMaster protocol and chosen to elicit a HR ≥160 bpm throughout. This intensity was chosen based on a previous study that used a discontinuous protocol in youth of normal weight and obesity to assess counterregulatory hormonal responses to acute exercise [26]. BP and HR were measured and recorded using the same procedures as visit one.

2.5. Data Processing and Analysis. One-way analysis of variance (ANOVA) tests were initially conducted to determine

Table 1: Participant demographics and characteristics, presented as frequencies and mean ± SD.

	NW	OB	PWS
Frequency	16	18	11
Male/female	7/9	12/6	8/3
Age (y)	9.4 ± 1.1‡	9.3 ± 1.1‡	11.4 ± 2.5
Pubertal stage (Tanner)			
I	9	9	3
II	4	5	2
III	3	3	2
IV	0	0	2
V	0	0	1
Body mass (kg)	32.76 ± 5.58	53.18 ± 13.31*	57.70 ± 22.67*
Body mass index z-score	−0.1 ± 0.6	2.0 ± 0.5*	1.7 ± 0.7*
Waist circumference (cm)	60.7 ± 4.4	85.3 ± 11.9*	84.1 ± 17.8*
Trunk fat (%)	16.7 ± 5.1	42.9 ± 7.8*	43.5 ± 8.4*
Fat mass (%)	18.7 ± 4.6	41.2 ± 7.5*	43.4 ± 8.2*
Lean mass (%)	78.1 ± 4.3	57.0 ± 7.2*	54.8 ± 7.8*
Lean mass (kg)	25.32 ± 3.91	29.31 ± 4.42	30.91 ± 11.92
Resting heart rate (bpm)	86 ± 10	80 ± 9	81 ± 13
Resting SBP (mm Hg)	99 ± 9	106 ± 11	113 ± 12*
Resting DBP (mm Hg)	60 ± 12	69 ± 11*	68 ± 6

Values are significant at $P < 0.050$; *different than NW; ‡different than PWS. Pubertal status was not obtained from one OB and one PWS.

group differences for participant characteristics and all exercise responses. HRRV was used to compare HRR among groups for both exercise intensities. ANOVAs were then conducted to determine group differences for HRRV for each exercise intensity. In case of significant group differences, Tukey's post hoc tests were used to determine pair-wise differences. Significance level for all statistical analyses was set at $P < 0.050$. IBM SPSS Statistics 19.0 for Windows (SPSS, Inc., Chicago, IL) was used for the statistical analysis.

3. Results

No sex differences were found between and within groups for HRR; therefore, all children were analyzed together. As expected, OB and PWS displayed a significantly greater total body mass, waist circumference, trunk body fat percentage, and total body fat percentage compared to NW. In contrast, NW had significantly greater lean mass percentage than their counterparts; there was no difference in lean mass percentage between OB and PWS (Table 1). All groups had a similar absolute peak workload, peak SBP, and peak DBP, while youth with PWS exhibited a lower relative peak power output (expressed per kg of lean body mass) and peak HR than NW or OB (see Table 2), who had similar relative peak workloads and HR. Absolute submaximal workload was also similar amongst groups; however, PWS had a lower relative power output than NW only during submaximal exercise (see Table 3)—OB children were not significantly different from either PWS or NW. When expressed as a percentage of peak relative workload, all groups worked at a similar aerobic effort during submaximal exercise (Table 3). All groups had significantly different mean submaximal exercise HR responses, with NW having the highest and PWS having the lowest (see Table 3). When expressed as a percentage of peak HR, the HR response during submaximal exercise was significantly lower in OB compared to NW; PWS was similar to both groups (Table 3). OB also had a significantly higher SBP in response to submaximal exercise compared to NW, and PWS had a similar response to both groups. All groups had a similar submaximal exercise DBP.

There were no significant group differences for HRRV from peak exercise. For submaximal intensity exercise, youth with PWS had a significantly lower HRRV compared to both NW and OB, who had similar HRRV (Figure 1).

4. Discussion

The results of this study showed that the decline in heart rate following exercise was not dependent on excessive adiposity. All groups had similar HRR in response to peak exercise. The only difference observed was in youth with PWS who displayed a significantly slower HRR following submaximal intensity exercise compared to other children. Two possible mechanisms explain the lower HRR following submaximal exercise in PWS: cardiovascular fitness and/or autonomic abnormality.

Children of normal weight and those with obesity but without PWS had similar recovery responses following both peak and submaximal aerobic exercises. Therefore, the results of this study contradicted the results of an earlier study by showing that increased adiposity did not affect postexercise HRR in children with nonsyndromic obesity [8]. However, there was a key methodological difference between the previous study [8] and the present study. The present study

Table 2: Responses to peak intensity exercise, presented as mean ± SD.

	NW	OB	PWS
Absolute peak power output (W)	96.7 ± 16.9	105.9 ± 21.4	94.6 ± 55.7
Relative peak power output (W·kg LBM^{-1})	3.8 ± 0.5‡	3.6 ± 0.7‡	2.9 ± 0.7
Peak heart rate (bpm)	186 ± 12‡	190 ± 14‡	167 ± 18
Peak SBP (mm Hg)	129 ± 19	142 ± 18	126 ± 20
Peak DBP (mm Hg)	63 ± 9	67 ± 13	69 ± 9

Values are significant at $P < 0.050$; ‡different than PWS.

Table 3: Responses to submaximal intensity exercise, presented as mean ± SD.

	NW	OB	PWS
Absolute submaximal power output (W)	67.5 ± 14.0	69.0 ± 14.8	64.8 ± 31.3
Relative submaximal power output (W·kg LBM^{-1})	2.7 ± 0.4	2.4 ± 0.4	2.1 ± 0.3*
Percentage of peak relative workload (%)	70.9 ± 15.0	65.9 ± 10.5	71.5 ± 10.5
Submaximal exercise heart rate (bpm)	170 ± 8‡	161 ± 9*	148 ± 15*,†
Percentage of peak heart rate (%)	91.6 ± 5.5	85.1 ± 6.1*	88.7 ± 5.4
Submaximal SBP (mm Hg)	122 ± 12	136 ± 12*	129 ± 20
Submaximal DBP (mm Hg)	58 ± 14	65 ± 11	65 ± 10

Values are significant at $P < 0.050$; *different than NW; †different than OB; ‡different than PWS.

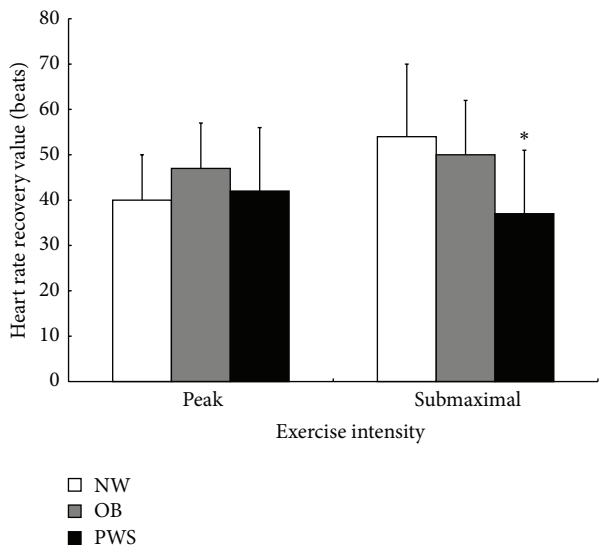

Figure 1: Postexercise HRRV (beats) by group and exercise intensity, presented as mean ± SD; $^{*}P < 0.050$.

measured passive (i.e., no cool down, seated) HRR immediately following test termination. By doing so, postexercise HRR was not affected by continued, voluntary sympathetic activation (which occurs during active cool down) and better isolated true recovery rate.

Another factor that could have influenced the HRR results of this study is cardiovascular fitness. Higher levels of cardiovascular fitness have been positively associated with a faster HRR following exercise [27–31]. Adults with high levels of physical activity have shown to either sustain or improve HRR over 20 years compared to adults with low levels of physical activity [28]. In addition, HRR improved after exercise training and a hypocaloric diet in obese children [31]. The fact that cardiovascular fitness is related to HRR may partially explain the results of this study. Both participants with obesity and those of normal weight were similarly fit (i.e., peak W·kg LBM^{-1}, peak HR, and peak estimated [23] VO_{2peak} (13.9 ± 1.0 versus 13.6 ± 1.2 mL·kg LBM^{-1}·min)). In contrast, those with PWS were significantly less fit compared to children without PWS (i.e., lower peak HR, lower W·kg LBM^{-1}and lower estimated [23] VO_{2peak} (12.4 ± 1.3 mL·kg LBM^{-1}·min)). Previous work showed poor cardiovascular fitness and low physical activity level in PWS [32, 33]. Poor cardiovascular fitness in PWS might be best explained by physiological characteristics inherent to the syndrome including hypotonia [32], reduced knee flexor and extensor muscle strength [34], and/or muscle fiber size deficiency and atrophy [35]. Therefore, the lower HRR after submaximal exercise in those with PWS compared to the other children possibly indicates that the low cardiovascular fitness in those with PWS was related to the slow HRR [28, 31, 36].

In addition, it is possible that HRR in PWS may have also been influenced by altered ANS function. A review by Haqq et al. suggests that in obesity there is an increased sympathetic activity as well as reduced parasympathetic activity [37]. This mechanism is not so clear in PWS, although it appears that PWS presents similarities with an autonomic disorder called familial dysautonomia where more sympathetic neurons are affected than parasympathetic neurons [37]. Richer and colleagues investigated a small cohort of children with PWS and controls to determine possible differences in ANS function. Postganglionic sympathetic function was evaluated through Quantitative Sudomotor Axon Reflex testing (sweat volume), cardiovagal testing (HR response to deep breathing), and pupillary response (HR and BP responses and HR variability spectral analysis to head-up tilt). Children with PWS exhibited a trend towards lower total sweat volume, a smaller HR increase with head tilt-up, and lower low frequency power

HR variability at rest and with head-up tilt compared to the controls indicating possible impaired sympathetic function [15].

The results of the present study showed a lower peak HR in PWS perhaps related to lower muscular work capacity or sympathetic stimulation. However, the lower HRR following submaximal exercise in those with PWS compared to nonsyndromal children may indicate a delayed sympathetic withdrawal and impaired function as suggested by Richer and colleagues [15]. In terms of peak exercise responses, it is possible that the chosen protocol limited the capacity to fully assess ANS function, and therefore no differences among groups were obtained. Past studies suggested that after peak intensity exercise HRR is delayed due to sympathetic activity lasting one to three minutes into the recovery period. The present study measured HRR only during the first minute after exercise, and this is a limitation of the study design and results [2, 5].

In addition, the participants with PWS were significantly older than nonsyndromal obese controls, which might explain the deterioration in ANS function [38]. Seven youth with PWS presented Tanner stages I–III, while two youth presented stage IV and one stage V. In comparison, all nonsyndromal children presented Tanner stages I through III based on their self-report. Follow-up analyses were done to determine differences among groups in HRR including only participants with Tanner stages I through III. Youth with PWS ($n = 7$) still presented a significantly slower HRR following submaximal intensity exercise compared to NW ($n = 16$). However, OB ($n = 17$) responded similarly to both groups following submaximal exercise. Similar to the previous analyses, no group differences were observed following maximal intensity exercise. It is possible that those youth with PWS in later stages of puberty experienced more ANS deterioration, exacerbating the HRR differences with the nonsyndromal obese controls. Regardless, youth with PWS still showed a delayed recovery from submaximal intensity exercise compared with normal weight controls, indicating possible ANS dysfunction. It is necessary for future studies to account for pubertal status as a screening criterion to better assess whether the differences in HRR are related to ANS function. Lastly, recording blood pressure at the end of the recovery period is another measurement that could have helped assess the ANS function in response to exercise. Overall, the results of this study suggest that ANS dysfunction in youth with PWS could influence HRR following submaximal intensity exercise.

Having participants with PWS complete these protocols presented barriers. Most of these limitations were related to the physiological (lower than normal muscle force capacity, lack of stamina, and lower than normal motor proficiency), psychological (mild to severe mental retardation and mental rigidity), and behavioral (attention deficit, temper tantrums, and inability to accept change) characteristics of PWS [13, 14, 32, 33, 39]. Even with these difficulties, those with PWS were able to complete a graded peak exercise protocol. It was verified that the submaximal effort was similar between those with and without PWS by calculating the percentage of relative power output and heart rate compared to peak effort. Therefore, the present study results were not affected by the exercise protocols. The present study lacked comparison groups with low and high cardiovascular fitnesses, a comparison that would have isolated the effect of cardiovascular fitness on HRR. However, a study with such research design may not be feasible given that inherently PWS presents poor cardiovascular fitness.

5. Conclusion

As demonstrated by the similar recovery rate in children of normal weight and those with obesity, adiposity did not influence HRR following peak or submaximal exercise. Youth with PWS showed a low cardiovascular recovery capacity, suggesting that poor cardiovascular fitness and/or an altered ANS function may impact HRR.

Conflict of Interests

The authors claim no conflict of interests for this paper.

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Research Article

Experimental Evidence on the Impact of Food Advertising on Children's Knowledge about and Preferences for Healthful Food

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To understand the rising prevalence of childhood obesity in affluent societies, it is necessary to take into account the growing obesity infrastructure, which over past decades has developed into an obesogenic environment. This study examines the effects of one of the constituent factors of consumer societies and a potential contributory factor to childhood obesity: commercial food communication targeted to children. Specifically, it investigates the impact of TV advertising on children's food knowledge and food preferences and correlates these findings with their weight status. Evaluations of traditional information- and education-based interventions suggest that they may not sustainably change food patterns. Based on prior consumer research, we propose five hypotheses, which we then test using a subsample from the IDEFICS study, a large-scale pan-European intervention study on childhood obesity. The results indicate that advertising has divergent effects on children's food knowledge and preferences and that food knowledge is unrelated to food preferences. This finding has important implications for both future research and public policy.

1. Background and Aim of the Study

In consumer societies, modern diets based on unhealthy fast foods, convenience foods, energy dense snacks, and soft drinks, the abundance and omnipresence of food, and sedentary lifestyles and electronic recreation that minimises physical activity have led to serious weight control problems. A particularly severe trend impacting future health levels are the high, and in most countries still rising, levels of overweight and obesity in infants and children [1]. According to statistics provided by the World Health Organization [2], the Organisation for Economic Co-operation and Development [3], and the International Obesity Task Force (IOTF) (http://www.iaso.org/iotf/obesity/), the problem is increasing and steadily affecting many low- and middle-income countries. Globally, the number of overweight children under the age of five was estimated in 2010 to be over 42 million; close to 35 million of them living in developing countries. About 60% of children who are overweight before puberty will be overweight in early adulthood [4].

On an individual level, childhood obesity is strongly associated with risk factors for type 2 diabetes, cardiovascular disease, underachievement in school, and lower self-esteem. On a social level, it jeopardises societies' sustainability through the erosion of social cohesion, equity, and fairness. In the developed world, obesity is closely connected with low socioeconomic status (SES); that is, membership in groups for whom access to and availability and affordability of healthier food choices and physical activity is particularly limited [5]. There is also evidence that cumulative exposure to television food advertising—which is higher in lower SES groups—is linked to adult fast-food consumption [6].

Beyond individual and social problems, rising obesity rates impact healthcare systems and labour markets and

also carry environmental costs: modern diets in consumer societies, high in processed foods and animal protein, have a particularly negative ecological footprint—a long neglected fact that has given rise to a debate on "globesity" [7]. Put simply, halting and reversing current childhood obesity trends is not simply an imperative for public health policies but rather is increasingly understood as a broader societal challenge that has become an explicit goal of sustainability strategies worldwide [8]. As a result, addressing obesity among children and adolescents has become a top public health priority—particularly in the USA, which has one of the highest incidences of obesity worldwide [9].

1.1. Drivers and Impact of Childhood Obesity. In light of these challenges, researchers and policy makers have been focusing on the key drivers and barriers for healthy diets and healthy lives in childhood. Based on scientific evidence on the importance of the immediate "choice context" of the socialisation environment in which children acquire their food knowledge, develop preferences, and actually make food choices, the need to create "junk-free environments" for children has gained increasing support from health professionals, consumer advocates, and concerned political circles [10]. Attempts to steer children's preferences and food choices in a healthier direction, however, have limited success in an "obesogenic environment" [11], one that promotes unhealthy foodstuffs and offers limited incentives for healthy, active lifestyles.

Although this "infrastructure of obesity" comprises many levels, is highly complex, and includes many interacting factors (see Butland et al.'s [12] influential 2007 Foresight report on tackling obesity in Britain), the key influential factors at work for children might, from a human ecological perspective, be roughly grouped by environmental type. Such ecological models, which consider individual behaviour in the context of multiple environments, offer a promising approach to obesity prevention [13–16]. In this paper, we focus on variables from the following three types of environments.

(i) *Social Environment*. Children are embedded in families, neighbourhoods, peer groups, schools, and child care facilities in which others influence their food preferences and practices by transposing their social norms and attitudes, food likes and dislikes, and consumption practices and affect their food habits through exposure and learning processes. These social groups also act as "communication buffers" between the children and the advertising and media messages that group members filter and evaluate.

(ii) *Physical Environment*. Children are directly exposed to a physical environment that offers or limits opportunities for physical activity (e.g., neighbourhood bikeability and walkability), access to healthful foods (e.g., accessibility and availability of healthy food in schools), and access to media (e.g., a TV in the child's own room). Such an environment thus provides both drivers and barriers for actors—from parents to community and school officials—to build "choice architectures" for more health-promoting environments.

(iii) *Media Environment*. The media environment and in particular commercial communication (e.g., food advertising and all kinds of stealth marketing) have been shown to shape food-related knowledge, attitudes, preferences, and practices both directly and indirectly. On a political level, regulation and self-regulation of advertising towards children are instruments that actively shape the media environment and potentially limit its influence on children's food preferences. A key moderating variable is children's advertising literacy or "ad smartness", which increases with cognitive development and hence children's age.

This present study, although it acknowledges the multitude of influential factors and the interactions within these three environments, focuses on only a few key factors, whose selection was driven by one widely accepted and empirically based assumption: children's exposure to highly sophisticated advertising messages, including less blunt forms of subtle "stealth" marketing techniques, together with ubiquitous food availability that encourages the consumption of calorie-dense food products of low nutritional value, is a major cause of children's unhealthy dietary choices [17, 18]. The question, therefore, is not *whether* food marketing to children works, but *how* it affects them. A better understanding of this process is a precondition for developing effective consumer policy tools to protect children from overexposure and imprinting. To enhance such understanding, this paper analyses the associations between TV food advertising and children's food knowledge, food preferences, diets, and weight status. Specifically, it draws on data for a subsample of the IDEFICS study [19], 229 elementary school children aged between 6 to 9 years from five European countries.

Before outlining our research design, we briefly sketch the key results of prior research on the impact of TV advertising on children's food knowledge and food preferences. Because the recent scientific literature offers comprehensive overviews on the state of the art in this field (e.g., [20–23]), we focus on the key variables in our study and their reported interrelations with each other and with advertising. Against this background, we develop our theoretical model and formulate the research hypotheses that guide our empirical study. After describing our methodology and analyses, we discuss our results as they relate to our hypotheses and conclude by outlining the policy implications of our findings.

1.2. The Impact of Food Advertising on Food Knowledge and Preferences. Children in Europe and the USA are heavily exposed to mass media, watching over two and a half hours of television daily on average (e.g., [24]). Depending on the children's age and taking into account multiuse of media, recent reports show an average media exposition of 8-to-18-year olds in the USA of more than seven hours per day [25]. Because ad-free noncommercial children's TV channels like those in Germany and Sweden are the exception, these hours of viewing bombard children with advertising [26]. As a result, in the USA, foods consumed in front of the TV account

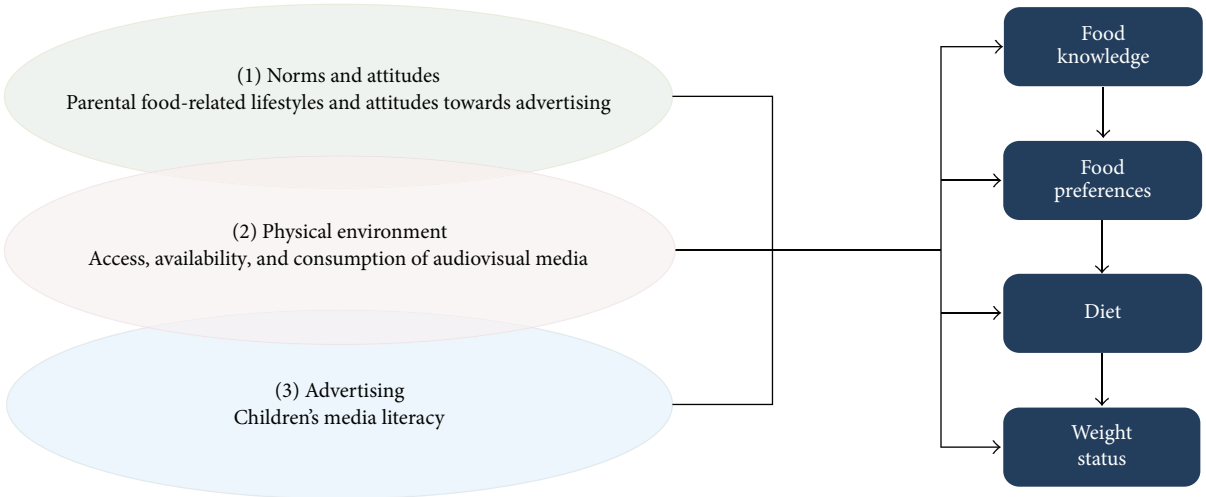

Figure 1: The role of commercial communication and food knowledge, preferences, diet, and weight status.

for about 20–25% of children's daily energy intake [27]. In the EU, the Audiovisual Media Directive limits product placement and commercial sponsoring during children's programmes while still leaving member states adequate leeway in audiovisual media regulation; nevertheless, limits are stricter in some EU countries than in others [28]. No such regulation exists in the USA, however, where children aged between 2 and 11 are exposed to about 25,000 commercials per year, some during adult programming like soap operas or cooking shows [29]. In the USA, 20% of these commercials are for food products, 98% of them high in sugar, fat, and/or sodium [20, 28]. The same holds true for Europe where the "big five"—sugared breakfast cereals, soft drinks, confectionary, savoury snacks, and fast food outlets—represent the majority of advertised food [22]. There is ample empirical evidence that such advertising content often leads to unhealthier food choices [30]. In fact, research identifies a direct causal effect of exposure to food advertising on *children's diet*; in particular, an increase in snack [31] and overall calorie consumption [17], an immediately lower intake of fruits and vegetables [32], and higher rates of obesity [33].

There is also empirical evidence that food advertising affects *knowledge* about (un)healthy nutrition: commercials for unhealthy foods relate directly to lower levels of nutritional knowledge (e.g., [34]). Advertising, therefore, seemingly overrides knowledge already acquired from other sources that promote healthier choices. In fact, effective advertising messages, rather than requiring active processing and understanding, imprint positive associations on children's brains that can be triggered in decision situations [35]. Nevertheless, evaluations based on comprehensive literature reviews [22, 36] conclude that the overall direct effect of advertising on children's food knowledge and preferences is modest rather than strong.

Empirical consumer research also shows that consumer knowledge does not necessarily lead to *preferences* for healthier food and that even if such preferences develop, they do not automatically guide behaviour. Thus, although most children and their families generally know what a healthy diet involves, their food choices often do not mirror this knowledge [37]. In fact, research indicates that accurate beliefs about food healthfulness are not associated with either food preferences or food consumption in children [38]. There is also evidence that the food choices of both children and their families are determined far more by attitudes and preferences than by acquired knowledge and that children are highly susceptible to the influence of peers in other social contexts [39]. Yet despite such evidence, prevention and intervention programmes usually take the educational approach [40].

Children's food preferences are also influenced by their immediate environment, particularly exposure to and familiarity with food stuffs, and by role models. Yet, according to the empirical literature [41], food advertising can influence children's preferences either way—healthier or unhealthier preferences [42]. Children also imitate their parents' (and other adult caretakers') food styles and learn by observation, meaning that they prefer eating fruits and vegetables if their parents do so. Their food preferences can also be influenced by sheer exposure to specific foods (the "I like what I know" phenomenon) [43].

2. The Study

2.1. The Human Ecological Model and Key Variables. This study investigates the association between food advertising and children's food knowledge, food preferences, diet, and weight status, as summarised in Figure 1. In line with the theory of human ecological development ("ecological model", [44]) and based on the literature sketched above, we select as our key variables potentially influential factors from the children's social, physical, and media environment; namely, food-related norms, attitudes, and lifestyles at home; the children's access to TV and consumption of TV commercials; and the children's level of advertising literacy. We also examine the relation between food knowledge, preferences, diet, and weight status.

2.2. Food-Related Norms and Attitudes. We measure the food and media setting at home by parents' general attitude towards advertising [45] and hypothesise that the more sceptical parents are about food advertising, the less susceptible their children are to the effects of advertising on food knowledge, preferences, diet and weight status:

H1: the more sceptical the parental attitude towards advertising, the better their children's food knowledge, the healthier their food preferences and diet, and the lower their weight status.

We also take into account the suggestion put forward in the consumer socialisation literature that if parents discuss and reflect on the aims of advertising with their children—for example, while watching TV together—they can help their offspring develop the "advertising literacy" [32] that is part of an effective advertising defence model:

H2: the fact that parents discuss the TV programmes/ads watched with their children influences these children's food knowledge, food preferences, diet, and consequently, weight status.

2.3. Access to and Consumption of Television Advertising. The potential impact of TV advertising is influenced by three variables: children's access to media, their penchants for TV programmes that carry more or less advertising, and their actual exposure. Unrestricted access increases hours of actual media exposure and influences the time of exposure to advertising, factors that are further augmented by children having a television in their own bedrooms [46]. The country of residence and the type of programme watched also influence exposure to advertising. Assuming the so-called "mere exposure effect", therefore—that is, that mere (and also incidental) exposure to advertising affects children's food knowledge and preferences—and accepting that advertising has the power to shape preferences [41], food knowledge should be lower [34] and preferences should be unhealthier when exposure is high. Such high exposure has consequences for both diet and weight status:

H3: unrestricted access and thus more exposure to advertising leads to lower food knowledge, unhealthier preferences, diets, and an unhealthier weight status.

2.4. Advertising Literacy. Children's handling of advertising depends on their advertising literacy—their knowledge about the goals and mechanisms of advertising—as well as on their attitudes towards advertising. In this context, knowledge refers to children's perceptions, including suspiciousness, of advertising's credibility and usefulness, whereas attitudes reflect the entertainment value that the advertisements hold for children [47]. Hence, following Livingstone and Helsper [32], we propose the following hypothesis:

H4: children's advertising literacy is related to their food knowledge, preferences, diets, and weight status; hence, higher advertising literacy is associated with better food knowledge, healthier preferences and diets, and lower weight.

2.5. The Relation between Food Knowledge, Preferences, Diet, and Weight Status. This study assumes a sequential relation between food knowledge, preferences, diet, and consequently weight status; that is, better food knowledge leads to healthier food preferences, which in turn lead to healthier food choices that are mirrored in a healthy weight status. As regards the effect of food knowledge on preferences, there is empirical evidence that in children accurate beliefs about food healthiness are not associated with food preferences or consumption [38]. Obviously, in the light of this finding, the widely held assumption that increased knowledge of healthy nutrition leads to healthier choices is a "misperception" [31, p. 223]. We therefore offer an alternative hypothesis:

H5: better food knowledge does not necessarily imply healthier food preferences (a), food preferences have no direct effect on dietary choice (b), and the latter has no significant effect on weight status (c).

3. Data and Methodology

3.1. Sample and Survey. The data used for our analyses were obtained in the context of the IDEFICS study, a prospective cohort study that began with a baseline survey in 2007/2008 and continued with a follow-up survey two years later [19]. The total IDEFICS cohort consists of 16,225 children aged 2 to 10 years from eight European countries. One unique feature of this study is that it employs a large number of objective measurements and supplements the questionnaire data with a large amount of laboratory data. For example, in the IDEFICS baseline survey, run between September 2007 and May 2008, parents described their children's lifestyle, television consumption habits, diets, parental attitudes and sociodemographic circumstances in a detailed self-administered questionnaire. A thorough physical examination was also conducted on all children in the sample to determine their amount of body fat, weight, height, and other health indicators [19]. To gather more specific information on the children's food knowledge and preferences as well as on their advertising literacy, between April and June 2009, we developed instruments (choice experiments and a questionnaire) and collected additional data for a subsample in five countries. Only children that participated in the experiments and the questionnaire are included in the present analysis. The resulting sample size is 229 children aged between 6 and 9 years (average age = 7.83; standard deviation (SD = .77)), 122 (53.3%) of whom are female. The participants are distributed as follows across the five countries: Belgium, 60 (26.2%), Estonia, 25 (10.9%), Germany, 48 (21.0%), Italy, 47 (20.5%), and Spain, 49 (21.4%).

3.2. Food Knowledge and Preferences: A Choice Experiment. The data on children's food knowledge and preferences were gathered via a choice experiment (see Gwozdz and Reisch [48]) based on Kopelman et al. [37] but adapted to our research question and settings. The primary stimuli were two brochures showing 10 matched pairs of food cards; one picturing relatively healthy food, the other relatively unhealthy food. As shown in Table 1, these matched pairs belong to

Table 1: Matched pairs of food cards based in part on Kopelman et al. [37].

Number	"Relatively healthy"	"Relatively unhealthy"
1	Sugar-free cereals (all kinds of sugar-free cereals)	Sugared cereals (including chocolate or crunchy cereals)
2	Water (all kinds of drinking water)	Coke (all kinds of coke)
3	Pasta (all types of noodle with home-made tomato sauce)	Pot noodle (all types of instant pasta soups or prepared pasta)
4	Cereal bar (low in sugar)	Chocolate bar (whole milk chocolate)
5	Roast beef (all types of fatless roast)	Beef burger
6	Strawberry yoghurt (all types of fruit yogurt, curd cheese, or buttermilk)	Strawberry cake (all types of fruit cakes)
7	Whole meal bread (all types of whole meal bread)	White bread (all kinds, including ciabatta, baguette, white toast)
8	Orange juice (100%) (all 100% fruit juices)	Orange squash (all types of fruit squash)
9	Potato (boiled or baked)	French fries (also fried potatoes, hash browns)
10	Orange (all types of fruits)	Orange ice (all types of fruit ice popsicles/lollipops)

the same respective food category (e.g., "juice"). (To minimise unintended influences, it would have been preferable to have the children choose between real food products instead of pictures; however, because the experiments were carried out in five different countries in which the same products were not available or known to the children, doing so was not an option. Rather, to ensure comparability between the countries, we chose the pictures as feasible alternative.)

The two-step experimental procedure included a preference test and a knowledge test. In the preference test, the children were asked, "Which food or drinks do you like best?" They then drew a smile (for "true") or a frown (for "false") for each matched pair according to their (forced-choice) preference. The knowledge test proceeded in a similar way. Again, the children drew a smile or a frown for each matched pair in reaction to the following question: "What do you think: Which food or drink is the healthier one?" This order was chosen based on pretest results showing that conducting the preference test first would reduce framing effects.

Based on the children's choice experiment scores (i.e., whether they chose healthier or unhealthier foods and drinks from the 10 matched pairs), we built one indicator for food knowledge and another for food preferences. Both indicators range between 0 (no healthy food chosen) and 10 (only healthy food chosen). We also created a dummy variable capturing high knowledge or healthy preferences whenever a score equalled 6 or above, i.e., 1 "score > 6" and 0 "score ≤ 6") (see [37]).

3.3. Measurement of Variables

3.3.1. Children's Diet. Our first diet measure reflects children's diet quality—including meal frequency, diet composition and variety, fast food consumption, and snack and beverage consumption—as well as family control [49]. This first dependent variable is a continuous variable that describes diet quality based on the Youth Healthy Eating Index (YHEI) [50], which ranges from 0 to 80, with a higher score signalling a more healthful diet. The YHEI, which measures food consumption and food-related behavioural patterns, is based on food frequencies, which in the IDEFICS survey are collected using the Children's Eating Habits Questionnaire (CEHQ) [51]. This latter asks parents for information on their children's food consumption of 43 predefined food categories, excluding foods served at school. The YHEI scores, therefore, measure solely the healthfulness of the diet under parental control. We do, however, also include meal pattern information from the CEHQ, such as frequencies of fast food consumption, breakfast at home or in school, and family dinners.

Based on these data, we are able to replicate 10 of the 13 original YHEI dimensions, which are listed below with nutritional values in brackets

Food types:

(1) whole grains (sources of fibre, vitamins, and minerals),

(2) vegetables (sources of vitamins and minerals),

(3) fruits (sources of vitamins),

(4) dairy (sources of calcium),

(5) snack foods (unnecessary energy),

(6) soda and drinks (unnecessary energy),

(7) margarine and butter (sources of fat).

Food behavioural patterns:

(8) fried foods outside home (high energy intake),

(9) eat breakfast (indicator of healthful dietary patterns),

(10) dinner with the family (indicator of healthful dietary patterns).

The original version of the YHEI also includes the dimensions "meat ratio", "multivitamin use," and "visible animal fat", but these factors are not covered in the IDEFICS data. We calculate the YHEI using the sum of all available subscores for the 10 dimensions, the criteria for which are adapted from Feskanich et al. [50].

The other two dietary measures mirror the relative intake of sugar and fat and thus also reflect diet quality. Specifically,

we calculated the weekly consumption frequencies of each of 12 foods and beverages that are high in sugar content and 17 foods and beverages that are high in fat and divided the weekly sugar and consumption by the individual's total consumed food frequencies (see [52]).

3.3.2. Children's Weight Status. The last set of dependent variables relate to the children's lagged weight status (in the follow-up survey, i.e., weight status two years after the baseline survey in 2007/2008). The IDEFICS data set provides several anthropometric measurements related to body composition, all measured by trained nurses based on the same standard operating procedures (SOPs) in all countries. Again, we used three different models to capture the weight status, each based on a different dependent variable.

(i) Model 1. We consider the body mass index (BMI = weight in kilograms by squared height in meters) as a continuous variable, calculated as usual as a z-score according to the growth charts from the Centers for Disease Control (CDC) [53].

(ii) Model 2. As a second anthropometric measure, we used the corresponding z-scores of waist circumference, based on the growth charts of the International Obesity Task Force (IOTF) [54].

(iii) Model 3. As a third measure, we used body fat mass, which must be calculated based on fat mass, as derived from Bammann et al.'s [55] "four component model", together with hip circumference and triceps skinfold.

3.3.3. Parental Norms, Attitudes, and Food Practices. Norms and attitudes reflect the influence of the "setting"; that is, the general parental attitudes toward advertising [56] and whether parents discuss the TV programmes watched with their child. Hence, parental attitudes towards advertising measure the perceived usefulness and credibility of ads, as well as the expected effects of the ads on their children. Borrowing from Diehl and Daum's [56] Attitudes Toward TV Food Advertising Aimed at Children scale (AFAC), we ran a factor analysis for identifying dimensions of parental attitudes towards advertising. (We carried out a principal component analysis with varimax rotation resulting in two factors. The eigenvalue is 1.44, the Kaiser-Meyer-Olkin measure is .651, and all factor loadings are above .405. Cronbach's Alpha for Factor 1 is .737 (four items) and for Factor 2 is .510 (three items).) The result was two factors with the following statements for Factor 1: ad usefulness and credibility: (a) TV food advertising is a good source of information for children and parents, (b) TV food advertising assists parents in their efforts to feed their child a healthy and balanced diet, (c) a child clearly understands just how good the product presented in TV advertising is, and (d) TV food advertising informs children and parents about things they would otherwise never learn about. For the second factor on the effect of TV food ads, we include the following three statements: (a) TV food advertising causes children and their parents to spend their money on unnecessary and sometimes even harmful products, (b) TV food advertising is largely responsible for the weight problems and bad teeth of many children, and (c) TV food advertising can hardly have an influence on what children eat and drink (reversed). Reversed items were recoded before the average score was calculated for each of the two dimensions. The question on discussing TV content with children is phrased as follows: "When watching TV, do you discuss the programme/ads with your child?" The variable is coded as a dummy: 0 = "never or sometimes"; 1 = "often or always".

3.3.4. Exposure to Media and Advertising. Other information for the direct advertising context stems from the IDEFICS baseline survey and comprises data related to the children's TV viewing habits: whether a television is available in the children's bedroom (dummy) and their weekly TV viewing time.

3.3.5. Children's Advertising Knowledge and Attitudes. The questionnaire used to measure children's advertising knowledge and attitudes is based on an instrument developed and validated by Diehl [47], which covers three dimensions, each measured by three questionnaire items: credibility, children's perception of TV advertisements as a useful source of information; suspiciousness, their questioning of commercial messages; and entertainment, the fun factor of watching commercials. The first dimension, the credibility and usefulness of food advertising, assesses whether children perceive TV advertisement as a useful source of information about foods and drinks. The hypothesis underlying the second dimension, suspiciousness toward food advertisements, is that if children are suspicious of TV food advertising, they will know not to trust any advertising content and will thus question commercial messages. The assumption underpinning the third dimension, the entertainment factor of TV advertising, is that children who are more suspicious and have less trust in the credibility of TV advertisements experience them as less entertaining. This latter implies that once children understand the mechanisms underlying advertising, they no longer enjoy watching them as much as before. To these three dimensions, we add an additional dimension, social desirability, measured on a four-point scale from "disagree fully" (−2) to "disagree" (−1), "agree" (+1), and "agree fully" (+2). Taking into account our respondents' young ages, we present the answer categories as pictograms ("smileys") instead of words, expressing the respective nuances of (dis)agreement with more or less happy faces. The suitability of this instrument was demonstrated in pretests [48].

3.3.6. Control Variables. The controls encompass socioeconomic status, indicated by the maximum parental education level (ISCED levels 1–6), child's age, child's sex, and country dummies. Thus, all analyses have been adjusted for these variables where child's age is introduced by three dummy variables: age <8 years, =8 years, and >8 years, the latter acting as the reference category. Child's sex is also expressed in form of a dummy variable (0 is male; 1 is female). For the five countries, we created five dummies, with Belgium acting as the reference group.

3.4. Statistical Analysis. To meet the study goals we use STATA/SE 11 software to carry out a set of ordinary least squares (OLS) or probit regressions in which food knowledge, preferences, diet, and weight status are the dependent variables. In a first step, we estimate the following regression model:

$$F = \beta_0 + \beta_1 \mathrm{DA} + \beta_2 \mathrm{IA} + \beta_3 C + \beta_4 D + \varepsilon, \quad (1)$$

where F is a vector for our measure for food knowledge or preferences and may have either continuous or discrete variables as defined above. DA is a vector of direct advertising context factors, IA is a vector of indirect advertising context factors, C is a vector of child and family characteristics, and D is a vector of country dummy variables (five countries, with Belgium as the reference country). ε is a vector of idiosyncratic error terms, and the βs are the coefficients to be estimated, with β_1 and β_2 being the coefficients of particular relevance in this study. Depending on the nature of F, we use either ordinary least squares or a probit model. Because we assume that knowledge is associated with preferences, we estimate the model on preferences a second time, now including food knowledge as an independent variable (see Figure 1).

In the next step, we first exchange the dependent variables knowledge and preferences with diet and then, in a third step, with lagged weight status. We then repeat the analyses. For weight status, we include an additional control variable in the form of a dummy variable indicating whether a child stems from the control or the intervention region in order to consider any possible intervention effect. For each analysis, we estimate two models for each dependent variable.

4. Results

4.1. Descriptive Statistics. Among the 229 children that participated in the choice experiment, the average score for food knowledge is 7.76 (SD = 1.18), higher than the average score of 4.78 (SD = 2.08) for food preferences, both measured on the same scale. Although 95% of the 229 children scored 6 or higher in the food knowledge experiment, only 33% chose 6 or more healthy foods in the preference experiment. As regards diet, the average YHEI is 49.6 on a scale between 0 and 80, the relative sugar intake is 27.9%, and the relative fat intake is 26.5%. As Table 4 also shows, diet quality and intake varies by country: Estonian and Spanish children show a higher diet quality and less sugar intake than children from the other countries. The lowest fat intake is among children from Italy and Spain. Belgian children, whose diet is comparatively high in relative sugar and fat intake, are the thinnest in the sample, with the lowest BMI, waist circumference, and fat mass. An overview of descriptive statistics of all used variables can be found Table 4.

Given the previously discussed assumption of a relation between food knowledge and preferences, we expect that both variables will influence children's diets and that diet in turn will be associated with weight. We therefore ran a correlation analysis for these dependent variables; however, we did not find any statistically significant correlation between food knowledge and food preferences (r = .109, P = .101). The diet variables themselves (YHEI, proportional sugar, and fat intake) are statistically significantly correlated—a high proportion of sugar or fat in the diet is linked to an unhealthful diet (YHEI) and vice versa—and as might be expected the strongest correlations occur between the weight status variables. Yet the correlation analysis reveals no indication of links between food knowledge and preferences and diet and weight status.

As regards the remaining variables, parents perceive advertising on average as having medium credibility (M = 1.86, SD = .69 on a scale from 0 to 4) and relate food advertising to negative effects on children's health (M = 2.74, SD = .61). In terms of access to media, analysed in terms of bedroom equipment and TV consumption time, about 38% of the children in the sample have a television in their bedroom; however, there are large differences between countries. The majority of children in Italy (82.6%) and Estonia (64.0%) have a television in their bedroom, followed by about a third of children in Germany (33.3%), but far fewer in Belgium (15.0%) and Spain (14.9%). The children spend an average of 1.32 hours per day watching TV.

The assessment of advertising knowledge and attitude, measured on a scale from −6 to +6, indicates that on average children feel more suspicious (M = 1.73, SD = 2.96) about advertising than they think it is credible or useful (M = .86, SD = 3.25) and entertaining (M = .13, SD = 2.82). In our sample, the most suspicious are the Italian children (M = 3.87, SD = 2.20) while the least suspicious are the Spanish (M = .87, SD = 3.17) and Estonian children (M = .79, SD = 3.05). The Spanish children also perceive advertising as entertaining (M = .90, SD = 3.20) and believe in its credibility as a source of information (M = 1.15, SD = 3.28) more than any other national group except for Belgian children (M = 1.78, SD = 2.97). The Estonian children are the most critical: they are the least entertained by advertising (M = −1.88, SD = 2.83) and perceive food advertising as the least credible (M = −1.40, SD = 3.28). Overall, we observe a variation by country; however, because our small sample size precludes any analyses stratified by country, we must rather rely on the inclusion of country dummies as control variables.

4.2. Associations between Advertising and Food Knowledge and Preferences. In this section, we investigate the associations between the variables discussed above: parental norms and attitudes, access and exposure (as well as advertising knowledge), and food knowledge, preferences, diet, and weight status. Table 2 presents the estimates of the food knowledge and preferences regressions, those for the continuous dependent variables in columns 1 and 3 and those for the dependent dummy variables on knowledge and preferences in column 2 and 5. The results reported in columns 4 and 6 are for the models that include food knowledge as an independent variable.

As the table shows, there is an apparent significant relation between parental norms and attitudes: if parental attitudes towards advertising are critical (i.e., if they believe that food advertising has a negative effect on children's dietary behaviour), children's food preferences are more

Table 2: Role of commercials on food knowledge and preferences: OLS/probit estimates.

	Knowledge (1–10) OLS	Knowledge (>6, dummy) Probit	Preferences (1–10) OLS		Preferences (>6, dummy) Probit	
	(1)	(2)	(3)	(4)	(5)	(6)
(A) Parental norms and attitudes						
H1: attitudes towards ads (parents): usefulness and credibility	.071	.036	.014	.008	.089	.088
	(.123)	(.291)	(.243)	(.242)	(.148)	(.148)
H1: attitudes towards ads (parents): effects of ads	−.112	−.160	.266	.276	.271*	.272*
	(.106)	(.224)	(.254)	(.255)	(.149)	(.148)
H2: discussing TV programs with child	−.181	.017	−.211	−.195	−.107	−.108
	(.191)	(.433)	(.349)	(.351)	(.228)	(.229)
(B) Physical environment						
H3: TV consumption (hours per day)	.061	.268	.145	.140	.049	.048
	(.116)	(.220)	(.191)	(.193)	(.130)	(.130)
H3: bedroom equipment	−.286	−.457	.301	.327	.120	.206
	(.185)	(.386)	(.432)	(.440)	(.242)	(.243)
(C) Advertising						
H4: credibility dimension	−.031	−.031	−.034	−.032	−.056*	−.055*
	(.021)	(.041)	(.051)	(.052)	(.033)	(.033)
H4: suspiciousness dimension	.018	−.054	.027	.025	−.016	−.015
	(.024)	(.056)	(.059)	(.059)	(.036)	(.036)
H4: entertainment dimension	−.087***	−.097*	−.049	−.041	−.022	−.021
	(.027)	(.051)	(.059)	(.063)	(.038)	(.038)
(D) Food knowledge						
H5: food knowledge				.090		.191
				(.159)		(.468)
Observations	204	204	204	204	204	204
R^2	.276	.184	.080	.081	.069	.069
F-value/Wald χ^2	7.73	28.52	1.10	1.13	17.02	17.68
P value	.000	.008	.360	.334	.255	.280

Robust standard errors in parentheses; control variables are sex and age of child, parental education (ISCED), and country dummies. Reference category for age is 9 years and for countries, Belgium.
$^{*}P < .1$; $^{**}P < .05$; $^{***}P < .01$.
OLS: ordinary least squares estimator.

healthful (e.g., $\beta = .271$, SD = .149, column 5). Other parental attitudes, however, do not appear to be statistically significant. Access to media, on the one hand, shows no statistically significant effects: it seemingly plays no role in either food knowledge or preferences. Media literacy and food knowledge, on the other hand, are related along the entertainment dimension: children who are entertained by ads show also less healthy food knowledge than others. In terms of advertising, the statistical significance of advertising's credibility on food preferences is especially noteworthy: we find a highly significant negative effect of advertising's credibility on food preferences, meaning that children who are less sceptical of advertising have less healthful food preferences. Not surprisingly, given the prior finding in the correlation analysis of no relation between food knowledge and preferences, the introduction of food knowledge into the preference models (columns 4 and 6) does not improve the models: there is no change in adjusted R^2 and food knowledge is not significantly associated with food preferences.

4.3. Associations between Advertising, Food-Related Lifestyles, and Diet. Table 3 shows the results for the role of commercial communication on diet. On the one hand, we find that diet quality (YHEI) and fat intake are associated with parental norms and attitudes when such attitudes are critical of advertising. That is, in direct contrast to our expectations, the more critical the parents, the less healthful a child's diet and the higher the proportional fat intake. One possible reason for this unexpected finding could be social desirability effect, although a reactionary effect of children to parents' effort to make them eat healthily could also be at work. Such speculation, however, cannot be tested using the available data. On the other hand, we find no direct evidence of an influence of TV consumption on diet, although children with equipment in their bedroom show a higher proportion of

Table 3: Role of commercials on diet: OLS.

	YHEI		Relative sugar intake		Relative fat intake	
	(1)	(2)	(3)	(4)	(5)	(6)
(A) Parental norms and attitudes						
H1: attitudes towards ads (parents): usefulness and credibility	.177	.228	1.355	1.214	−.904	−1.584
	(.800)	(.869)	(1.190)	(1.320)	(.960)	(1.040)
H1: attitudes towards ads (parents): effects of ads	−.966	−1.298*	.941	.523	3.388*	2.682*
	(.674)	(.778)	(1.140)	(1.370)	(1.040)	(1.190)
H2: discussing TV programmes with child	1.270	1.443	−.565	.725	−2.800*	−2.640
	(1.190)	(1.390)	(1.600)	(1.950)	(1.380)	(1.620)
(B) Physical environment						
H3: TV consumption (hours per day)	−.843	−.941	.792	.809	.334	1.034
	(.658)	(.748)	(1.030)	(1.160)	(.908)	(1.010)
H3: bedroom equipment	−.341	−.207	3.354*	3.106	−1.505	−.922
	(1.190)	(1.350)	(1.790)	(1.970)	(1.540)	(1.760)
(C) Advertising						
H4: credibility dimension	−.234	−.301*	.735***	.534**	.343	.264
	(.144)	(.154)	(.216)	(.246)	(.210)	(.234)
H4: suspiciousness dimension	.100	−.013	.079	.272	.031	.303
	(.170)	(.197)	(.240)	(.272)	(.214)	(.238)
H4: entertainment dimension	.413***	.397***	.097	.031	−.124	−.224
	(.159)	(.192)	(.295)	(.345)	(.241)	(.281)
(D) food knowledge and preferences						
H5: food knowledge		.290		−.346		.478
		(.590)		(.895)		(.701)
H5: food preference		−.393		.301		.202
		(.239)		(.351)		(.295)
Observations	216	183	235	200	235	200
R^2	.147	.178	.143	.152	.143	.166
F-value/Wald χ^2	3.24	2.78	2.93	2.78	2.22	2.03
P value	.000	.000	.000	.000	.008	.013

Robust standard errors in parentheses; control variables are sex and age of child, parental education (ISCED), and country dummies. Reference category for age is 9 years and for countries Belgium.
$^{*}P < .1$; $^{**}P < .05$; $^{***}P < .01$.
OLS: ordinary least squares estimator.

sugar intake in their diet (e.g., one TV increases the share of sugar by 3.35%). Advertising literacy, however, is statistically significant in two cases: the more children feel entertained by advertising, the more healthful their diet—which once again stands in contrast to our expectations. The positive association between a higher credibility and usefulness of advertising and the relative high sugar intake, however, is in line with our fourth hypothesis (H4). Our introduction of food knowledge and preferences into the models (columns 2, 4, and 6) does show they have a statistically significant effect on diet and the adjusted R^2 indicates an improvement.

4.4. Associations between Advertising and Children's Weight Status. We also ran regression analyses for estimating the relationship between advertising and children's weight status. The dependent variables are BMI (CDC, z-score), waist circumference (Cole, z-score), and relative body fat (kg/m^2). We find no association between weight status and either parental norms and attitudes or the physical environment. We do show that children who are suspicious of ads have a higher BMI (column 2); however, only when diet factors are included. In fact, diet seems to have an influence on weight status; rather, counterintuitively, the proportional sugar intake is statistically significantly in relation to the lagged weight status, indicating that the higher the share of sugar in a diet, the lower the weight status. Neither the diet quality nor the proportional fat intake are statistically significantly associated with lagged weight status.

In sum, our findings are rather mixed. Although some factors of the attitudes and norms environment show effects in the predicted direction on the healthfulness of food preferences and diet (diet quality and proportional fat intake), we

Table 4: Descriptive statistics.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Dependent variables					
Food knowledge	229	7.76	1.18	3	10
Food knowledge > 6	229	.95	.22	0	1
Food preferences	229	4.78	2.08	0	10
Food preferences > 6	229	.33	.47	0	1
Diet quality: YHEI	201	49.60	7.63	25.9	69.0
Relative sugar intake (%)	224	27.94	11.13	2.8	55.8
Relative fat intake (%)	224	26.52	1.00	6.1	58.7
BMI (CDC, z-score)	181	.25	1.12	−2.8	2.4
Waist circumference (Cole, z-score)	181	.68	1.19	−1.99	3.34
Relative body fat (kg/m^2)	179	3.13	2.18	0	10.36
(a) Parental norms and attitudes					
H1: attitudes towards ads (parents): usefulness and credibility	225	3.14	.69	1	4
H1: attitudes towards ads (parents): effects of ads	225	2.31	.64	1	4
H2: discussing TV programmes with child	222	.35	.48	0	1
(b) Physical environment					
H3: TV consumption (hours per day)	224	1.32	.76	.07	4
H3: bedroom equipment	226	.38	.49	0	1
(c) Advertising					
H4: credibility dimension	227	.86	3.25	−6	6
H4: suspiciousness dimension	222	1.73	2.96	−6	6
H4: entertainment dimension	225	.13	2.82	−6	6
Controls					
Belgium	229	.26	.44	0	1
Estonia	229	.21	.40	0	1
Germany	229	.11	.31	0	1
Italy	229	.21	.41	0	1
Spain	229	.21	.41	0	1
Sex child	229	.53	.50	0	1
ISCED max.	228	3.72	1.11	0	6

find no robust associations between the physical environment and food knowledge, preferences, diet, or weight status. If we substitute TV consumption with audiovisual media (AVM) consumption (TV plus computer, game console consumption time), however, there is a statistically positive association between AVM time and weight status. The media environment (i.e., media literacy), however, seems to have the hypothesised effects on food knowledge and preferences but not on diet and weight status.

5. Discussion and Conclusions

This analysis, based on a subsample from the IDEFICS study, examines the effects of advertising on children's food knowledge and preferences, as well as on dietary choices and weight status. For the sake of focusing on the role of commercial communication, we do neglect possible impacts of genetic as well as lifestyle factors—which may indeed modify appetite, food intake, and preferences—in our analysis. Both types of factors and their influence have been studied within the IDEFICS study and will be published elsewhere. The key findings of our study are that better food knowledge is not seemingly linked to healthier food preferences and diet apparently has no significant effect on weight status. Although we acknowledge that the study is limited in sample size and operationalisation of the variables is based on our own reasoning and hence could be debated, these key findings do stand on robust empirical ground based on the analysis presented in this paper.

We interpret our results in light of the frequent claims that effectively countering harmful food marketing practices requires child awareness and understanding, paired with the ability and motivation to resist [31]. Many empirical studies, as well as evaluations of health intervention programmes, have indeed shown that providing information and education alone—the major policy strategy of recent decades—fails to successfully decrease advertising's effects on children. One reason that advertising literacy alone does not seem to help is that this knowledge only guides behaviour when it is accessed and used at the same time as the advertising stimulus, something that marketers carefully avoid. In addition, different processes of persuasion operate at different

age levels—that is, at different perceptual stages and levels of advertising literacy—which age-specific advertising takes into account [32]. Yet, although consumer policy efforts to strengthen children's ability to resist food industry lures have been part of many educational programmes on media literacy and consumer competence-building since the 1970s, no effective "food marketing defense model" [31] has been developed. The findings of this study provide further evidence that any such effort must go beyond informational approaches.

Overall, our findings support the contention that traditional policy strategies, based primarily on informational and educational goals, are insufficient to decrease the effects of advertising on children. Hence, although food smartness and advertising literacy will remain unquestioned goals of young consumers' socialisation, they cannot be expected to adequately guide behaviour in a healthier direction [57]. A more promising policy approach might lie in the tools of behaviourally informed social regulation suggested in the behavioural economics literature on "nudging" [58]. From this perspective, parents and caretakers should be aware of their decisive role as "choice architects"; as artisans who guide their children's selections by regularly offering healthful and attractive food and limiting their exposure to television and other sedentary behaviours. Hence, the old WHO motto "making the healthy choice the easy choice" should be reassessed and taken more seriously by everyone responsible for children's diet. Above all, food choices are strongly affected by the "triple A" of food items—availability, affordability, and accessibility—particularly if paired with and supported by social norms [59]. For instance, customer's food choices can be strongly influenced by the mere promotion of healthful food choices in "smart canteens" that offer the healthier choice as the default option [60]. This influence is, of course, no news for marketing professionals, but the power of context and the limited cognitive involvement of consumers in habitual consumer behaviours have too long been neglected by policy makers and health professionals alike. These latter particularly must recognise that a junk-free, nonobesogenic environment may be a necessary condition for successfully reducing obesity rates.

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Research Article

Towards Health in All Policies for Childhood Obesity Prevention

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The childhood obesity epidemic can be best tackled by means of an integrated approach, which is enabled by integrated public health policies, or *Health in All Policies*. Integrated policies are developed through intersectoral collaboration between local government policy makers from health and nonhealth sectors. Such *intersectoral collaboration* has been proved to be difficult. In this study, we investigated which resources influence intersectoral collaboration. The *behavior change wheel* framework was used to categorize motivation-, capability-, and opportunity-related resources for intersectoral collaboration. In-depth interviews were held with eight officials representing 10 non-health policy sectors within a local government. Results showed that health and non-health policy sectors did not share policy goals, which decreased motivation for intersectoral collaboration. Awareness of the linkage between health and nonhealth policy sectors was limited, and management was not involved in creating such awareness, which reduced the capability for intersectoral collaboration. Insufficient organizational resources and structures reduced opportunities for intersectoral collaboration. To stimulate intersectoral collaboration to prevent childhood obesity, we recommend that public health professionals should reframe health goals in the terminology of nonhealth policy sectors, that municipal department managers should increase awareness of public health in non-health policy sectors, and that flatter organizational structures should be established.

1. Introduction

Childhood obesity is currently considered an epidemic. Prevalence rates have doubled over the last three decades. Globally, approximately 180 million children (<18 years) are estimated to be overweight or obese [1–3]. In 2010, 43 million of them were under the age of five [3]. This rapid development has focused much attention on the problem (e.g., [4, 5]), especially since childhood obesity is associated with many health problems [6]; it often tracks into adulthood [7] and causes huge rises in health care costs [8].

The childhood obesity epidemic shows predictable patterns in almost all countries, due to similar systemic drivers (policies and economic systems) and environmental drivers (marketing of energy-dense foods and facilitation of passive transport) promoting overconsumption and physical inactivity [4]. Interaction between individual factors (e.g., genetic predispositions) and the environments in which children

grow up (e.g., their neighborhoods) lead to behaviors that cause a positive energy balance and in the long run weight gain [9]. In view of these drivers and the related economic and public health consequences of obesity, many experts have stressed the need for governments to take action (e.g., [10]).

Since it is recognized that health, and specifically obesity, is influenced by determinants not only within the health domain, but also outside this domain, experts recommend the implementation of an "integrated approach" for this so-called "wicked problem" [11–14]. An integrated approach is characterized by a mixture of coordinated interventions and policies by multiple disciplines, organizations, and sectors. Integrated public health policies, often referred to as "*Health in All Policies*" (HiAPs), are an important part of any integrated approach since they enable its implementation [13]. The HiAP approach is defined as: "*a horizontal, complementary policy-related strategy with a high potential for contributing to population health*" [11, 12]. The terms "horizontal" and "complementary" refer to the distinguishing feature of "integrated" compared to "regular" health policies, namely, intersectoral collaboration. Ensuring that health is taken into account in policies that are developed in other policy sectors requires close collaboration with these other sectors within government; thus, intersectoral collaboration is a prerequisite for the development of integrated public health policies [13]. An example of such an integrated policy developed through intersectoral collaboration is the policy to encourage active transport by improving road safety (collaboration between the public health and transport sectors). The implementation of such policies has been proved to be difficult; barriers are inherent to the *intersectoral* as opposed to *intersectoral* character of the collaboration and thus hamper the development of integrated public health policies [15–18]. Moreover, research shows that intersectoral collaboration within local governments is rarely established, and attempts to explore which factors cause this lack of collaboration have been scarce [19]. Some studies suggest that factors related to the topic of "childhood obesity prevention" (content-related factors) are responsible for the lack of intersectoral collaboration, while other studies suggest factors related to the process of intersectoral collaboration (process-related factors). Table 1 lists examples of these factors, based on an exploration of the literature. The literature review did not aim to be exhaustive but to provide a panoramic view of possible barriers and facilitators.

A limitation of these studies is that most of them were conducted in the context of organizations (e.g., focusing on interorganizational relationships) or community coalitions, and few specifically focused on the development of integrated public health policies to prevent childhood obesity within local governments. Therefore, this study focused on the resources (i.e., facilitators and barriers) regarding intersectoral collaboration for public health in general, and for childhood obesity prevention specifically.

To capture the resources needed for intersectoral collaboration and the development of integrated public health policies, we have used the "behavior change wheel" framework developed by Michie et al. [20, 21] (Figure 1). We adopted this framework since it provides a clear structure for reflecting upon resources for intersectoral collaboration and thus could help us answer our research question.

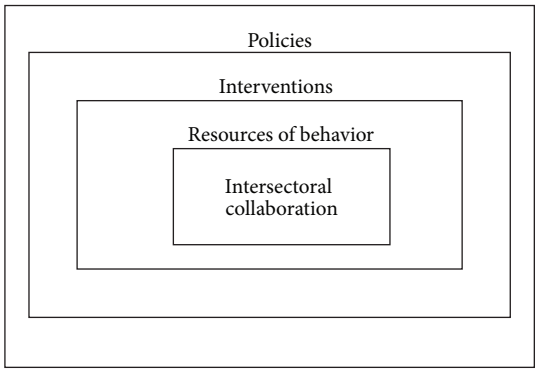

Figure 1: The behavior change wheel, adapted from Michie et al. [21].

The framework is based on the idea that behavior is determined by the following three resources: motivation, capability, and opportunity. If one of these resources is lacking or insufficiently present, behavior change interventions, which can be implemented by certain policies or programs (the outermost circle), might be needed to increase the likelihood of achieving intersectoral collaboration [20–22]. The present study focuses on the resources for intersectoral collaboration, as described below.

Motivation can be divided into reflective and automatic processes. Reflective motivation involves more conscious decision-making in evaluations and plans [21]. An example is having positive beliefs about the outcomes of intersectoral collaboration. Automatic motivation is based on emotions and impulses that arise from associative learning or innate dispositions. An example of automatic motivation is experiencing work engagement [48].

Capability is the extent to which individuals can adapt to change, generate new knowledge, and continue to improve their performance [49]: "*capability is what people are able to do and to be*" [50]. Psychological capability refers to the capability to engage in the necessary thought processes such as comprehension and reasoning [21], and it is closely related to competence, which refers to what individuals know or are able to do [49]. An example of psychological capability is having boundary-spanning skills [51].

Opportunity refers to conditions that are external to the individual actor. Two forms of opportunity are distinguished: physical and social. Physical opportunity is afforded by the working environment (e.g., organizational structures), while social opportunity refers to the municipal situation that dictates the way people think about things, the words and concepts they use, and the predominant discourse (e.g., organizational culture) [21].

The current dearth of knowledge regarding factors that facilitate or hamper intersectoral collaboration within local governments might explain why integrated public health policies have not been frequently applied in practice. Therefore, we aimed to answer the following research question: *What resources do local nonhealth policy makers need in*

Table 1: Barriers and facilitators regarding intersectoral collaboration.

Barriers regarding intersectoral collaboration	Reference
Content-related barriers	
Lack of awareness of the childhood obesity problem in nonhealth sectors.	Aarts et al. [23]
Limited involvement from other sectors in developing cross-sectoral policies.	Thow et al. [24]
Lack of political support for creating activity-friendly neighborhoods.	Aarts et al. [23]
Neoliberal political climate and individualistic societal climate.	Schwartz and Brownell [25]
Ambiguous political climate, governments do not seem eager to implement restrictive or legislative policy measures since this would mean they have to confront powerful lobbies by private companies.	Nestle [26] Peeler et al. [27] Verduin et al. [28]
Relevance to government's fiscal priorities was important in gaining support for soft drink taxes.	Thow et al. [29]
Lack of agenda-setting: lack of relevance and competing priorities.	Allender et al. [30]
Promoting healthy eating environments is not considered a greater priority for local government than food safety.	Allender et al. [31] Caraher and Coveney [32]
Other legislated planning guidance may take priority for planning and transport professionals.	Bovill [33]
Focusing only on health concerns: not taking into account policy issues of other sectors.	Thow et al. [24]
"Wicked" nature of obesity making it very unattractive to invest in its prevention.	Head [34]
Complexity of the legislative framework.	Allender et al. [35]
Low probability of decreasing the incidence of childhood obesity within the short timeframe that most politicians work in (which is determined by election frequencies).	Aarts et al. [23] Head [34]
Difficulty of developing consensus about ways to tackle the problem due to the lack of hard scientific evidence about effective solutions.	Aarts et al. [23] Head [34] Nishant et al. [36]
Framing of obesity as an individual health problem.	Dorfman and Wallack [37] Klein and Dietz [38] Phillips et al. [39] Merry [40]
Process-related barriers	
Local government officials lacking the knowledge and skills to collaborate with actors outside their own department.	Steenbakkers et al. [16]
Insufficient resources (time, budget).	Steenbakkers et al. [16] Woulfe et al. [18] Aarts et al. [23]
Lack of a clear enforcement mechanism.	Thow et al. [24]
Perceived or real lack of power to achieve change.	Thow et al. [29]
Government priorities change.	Nestle [26]
Lack of membership diversity in the collaborative partnerships.	Woulfe et al. [18]
Lack of clarity about the notion of intersectoral collaboration.	Harting et al. [19]
Top-down bureaucracy and hierarchy, disciplinarity and territoriality, sectoral budgets, and different priorities and procedures in each sector.	Bovill [33]
Insufficient organizational structures.	Steenbakkers et al. [16] Woulfe et al. [18] Alter and Hage [41] Hunter [42] Warner and Gould [43]
Poor quality of interpersonal or interorganizational relationships.	Woulfe et al. [18] Isett and Provan [44]
Lack of involvement by managers in collaborative efforts.	Steenbakkers et al. [45]
Lack of communication and insufficient joint planning.	R. Axelsson and S. B. Axelsson [46]
Lack of common vision and leadership.	Woulfe et al. [18] Hunter [42]

Table 1: Continued.

Facilitators regarding intersectoral collaboration	
Content-related facilitators	
Broad justification for the policy initiative.	Thow et al. [24]
Tailoring of information to the political context: information relevant to the government's agenda.	Schwartz and Brownell [25] Bowen and Zwi [47]
Political risk assessment and saleability.	Schwartz and Brownell [25]
Selection of policy tools that align with the government priorities (e.g., trade commitments)—ideally tools that are already used by trade policy makers in other contexts—and a broad justification for the policy initiative.	Thow et al. [24]
Process-related facilitators	
Policy change supported by external funding.	Thow et al. [29]
Cost-benefit analysis for any potential regulatory intervention.	Thow et al. [29]
Systematic evidence base to provide clear feedback on the size and scope of the obesity epidemic at a local level.	Thow et al. [29]
Sensitivity to community and market forces.	Thow et al. [29]
Suitable funding allowing local government to play a part in the promotion of healthy food environments.	Thow et al. [29]
Changing regulations to allow local government to play a part in the promotion of healthy food environments.	Thow et al. [29]
Strategically planning for agenda-setting.	Nestle [26]
Development and implementation of intersectoral health-promoting policies by engaging stakeholders in finance at an early stage to identify priorities and synergies.	Nestle [26]
Developing cross-sectoral advocacy coalitions.	Nestle [26]
Basing proposals on existing legislative mechanisms where possible.	Nestle [26]
Active involvement of health policy makers in initiating the policies.	Nestle [26]
Advocacy making policy uptake and implementation easier.	Thow et al. [24]
Use of existing taxation mechanisms enabling successful policy implementation.	Nestle [26]

Table 2: Policy sectors and participants.

Interviewed policy sectors	Participants (*n*): total (8), female (3) male (5)
Youth	(Official 1 (F))
Social affairs	(Official 1 (F))
Tourism	(Official 1 (F))
Municipal environment	(Officials 2 (M) and 3 (M))
Mobility	(Official 4 (M))
Public order and security	(Official 5 (F))
Sports	(Official 6 (M))
Culture	(Official 6 (M))
Education	(Official 6 (M))
Spatial planning	(Officials 7 (F) and 8 (M))

F: female, M: male.

order to collaborate with the health sector in the prevention of childhood obesity?

2. Methods

2.1. Study Sample and Design. In this study, we used a single-case study design [52] and in-depth semistructured interviews to collect our data. Our study sample consisted of eight policy officials working in a Dutch municipal government, responsible for 10 different policy sectors (some officials being responsible for more than one sector) (Table 2). At the time of the interviews (summer 2011), this municipal government employed 65 people. The municipality has around 11,000 inhabitants and covers an area of about 16 km^2.

Two interviewers jointly conducted all interviews: one (male) public health official working at the municipal government in which this study took place and one (female) university researcher. Afterwards, the two interviewers reflected on each of the interviews to compare notes and arrive at a more accurate interpretation of the data. Their reflections were entered into the reports that were sent afterwards to each of the interviewees and were also used in the data analysis. The interview reports were sent to the interviewees by way of member checks, in order to increase the reliability of our data. The interview protocol was jointly defined by the two interviewers (see appendix). Throughout the interview, we used childhood obesity prevention as an example of a public health problem that could be addressed more effectively if health and nonhealth sectors would collaborate. Our approach aim was to first focus on intersectoral collaboration for public health *in general* and then to focus on the prevention of childhood obesity. We assumed that this approach would reveal more information about resources for intersectoral collaboration than narrowing down our focus too early. Furthermore, we

assumed that resources for intersectoral collaboration would be comparable, as long as the policy issues that were being discussed had a "wicked" character [34].

2.2. Data Analysis. The university researcher transcribed the relevant parts of the interviews, categorizing them under subheadings that were based on our predefined interview items. She then sent the resulting reports to the public health official (the second interviewer), who sent them to the interviewees for a final accuracy check. Thus, the public health official was not only one of the interviewers, but he also assisted the researcher in conducting member checks. The interviewees were asked to send any comments to both interviewers. When the interviewees made any comments, the researcher checked and adjusted the transcripts and sent them once more to the public health official (the second interviewer). This approach ensured the accuracy of the transcripts. The transcripts were analyzed with the help of NVivo software, using the behavior change wheel as the theoretical framework to code the responses [21].

3. Results

Based on our analysis, we describe here the facilitators and barriers regarding intersectoral collaboration that we identified. Each facilitator or barrier is categorized under the factors of motivation, capability, or opportunity. For each quotation, we state whether the interviewee was male (M) or female (F) and the department for which they worked.

3.1. Motivation. The main perceived barrier to intersectoral collaboration that was mentioned during the interviews was that the health and nonhealth sectors did not have the same policy goals. This could reduce the motivation among nonhealth policy makers to involve the public health sector in an early stage of policy development and take aspects relevant to public health into account. Health was perceived as a side issue, as was expressed by a spatial planning official:

> *"Those are all side issues, as you start with a different goal in mind. Somebody comes along and says . . . I want to build a house, and it's only then that you start thinking, and then it's a matter of getting a house built there . . . You can come up with other things as you go along. . . . But our goal is not public health."* (F, spatial planning official.)

Nevertheless, policy goals were frequently similar, even if officials were not aware of this. For example, in the case of creating activity-friendly environments, similarities of policy goals were discovered during the interview; the transport department official commented how one of his policy goals, creating safe roads to walk and cycle on, had a positive effect on the residents' level of physical activity and thus affected public health:

> *"The idea of "sustainably safe" actually means that you try to design neighborhoods with that concept in mind, in other words, a 30 kilometers an hour speed limit."* (M, transport department official.)

As there were such similarities between policy goals, this facilitated intersectoral collaboration. However, most respondents seemed surprised, as they were not aware of the similarities, since they had never explicitly incorporated health in their policies. For example, the official responsible for youth services realized that she had not been paying attention to public health themes in her work routines, which she could easily have done:

> *"In children's and youth services you could . . . select themes that relate to health and overweight prevention."* (F, official for youth services, social services and tourism.)

Not only the health sector, but also other policy sectors with less dominant policy frames, such as that of municipal environment and tourism indicated that they tended to be "forgotten" when a new policy was being developed. For example, when a new residential area is being designed, the municipal environmental department was not involved until the project was nearly complete:

> *"Initiatives for construction work are first presented to the spatial planning department. . . . and they look mostly at the planning aspects. . . . So certain things tend to be overlooked at first."* (M, municipal environment official.)

Another barrier to collaboration with the health sector was the difficulty of making health goals visible and measurable. This appeared to cause stereotyping of the health sectors as being "soft" and "more interested in talking than doing," while nonhealth sectors (especially the more technically and construction-oriented departments) achieved "real" (visible and measurable) results. The stereotyped perceptions of the representatives of the various sectors were seen as an obstacle to intersectoral collaboration. In line with this, respondents emphasized that health and non-health sectors have different "world perspectives." According to the interviewees from the "welfare-oriented" sectors (i.e., policy sectors with the primary goal of increasing the subjective well-being of the citizens), the "technically oriented" sectors (i.e., policy sectors with the primary goal of improving the physical environment of the citizens) think health is important in life, but only after economic targets have been met:

> *"They look at certain things in a different way, they're people who have a very different background, different training. It's the sector of hard facts. They're concerned with money, bricks and mortar, they just have a different perspective.* (M, public health official and second interviewer.)

> *"they might exaggerate and say "You just talk about all kinds of stuff", and we would say "You never think about people"."* (F, official for youth services, social services and tourism.)

It was striking that the technically oriented sectors themselves were quite positive about taking health into account. They just framed their policy goals differently; instead of emphasizing

health outcomes, they used terms like "aging in place" (*levensloopbestendig*), "sustainably safe" (*duurzaam veilig*), "balanced" (*in evenwicht houden*), or "livability" (*leefbaarheid*) to express their views on preferred outcomes. One respondent referred to developments in a new residential area and their potential positive effects on public health:

> *"You can achieve that. . . . What you do take into account is whether it enables people to "age in place"."* (F, spatial planning official.)

Most respondents mentioned the territorial attitude of some policy makers; they defend their own work domain and do not allow others to get involved in their professional work, on principle. The extent of this territorial attitude also depends on people's individual character; the main personal factors that were mentioned were whether people trust their colleagues (i.e., feel it is safe to approach other policy actors) and whether they have an open personality (being positive about change, being receptive to new experiences):

> *"It's often a matter of character . . . people with a background in technology take a different view on people . . . they have very different characters."* (F, official for youth services, social services, and tourism.)

3.2. Capability. One of the barriers within the "capability" category was the lack of knowledge about the nature of public health:

> *"There's not a great deal of knowledge about health among the local authorities. . . . It's certainly not a bad idea to involve the regional Public Health Service"* (M, municipal environment official.)

Understanding how health should be taken into account and the importance of taking it into account was a "new" way of thinking for many non-health policy sectors. During the interview, one official from the spatial planning department admitted that she had always reduced public health to the presence or absence of illness rather than aspects like healthy lifestyle:

> *"We simply do not think about that. To me, public health is simply something like whether people get ill or not, and you do not build houses with that in mind."* (F, spatial planning official.)

To many municipal officials, and especially those with a non-health professional background, public health is a very "abstract" concept, which is not very visible to them. Non-health policy actors therefore frequently proposed to make the concept of public health more concrete. This could also improve the ability of non-health sectors to relate the outcomes of their own work to public health outcomes or to use public health as a vehicle to achieve their own policy goals (or the other way round). When talking about the influence of spatial planning on public health, both of the spatial planning officials we interviewed referred to their lack of awareness of ways they could improve public health. For example, both referred to their own policy themes, such as developing attractive green spaces and water features to improve the esthetics of the landscape, but they did not know this could also improve public health by encouraging people to go walking or cycling more often:

> *"Whether we do this consciously, I do not think so."* (F, spatial planning official.)

> *There are many things that you take care of, but without saying so. You incorporate those themes [i.e., themes that can affect public health] in your town planning designs . . .* (M, spatial planning official.)

In this context, the leading role of the heads of departments was also mentioned by one of the respondents; they should check whether policy proposals are integrated

> *"That would be my advice, that they should at least ensure that."* (Official for youth services, social services, and tourism.)

3.3. Opportunity. Facilitators in the opportunity category included the availability of sufficient resources (e.g., time, money, and policy free space) to adjust policy plans to ensure public health outcomes, and the recognition that citizens require facilities that promote health (recognizing that it is in the interest of citizens that municipal authorities pay attention to public health). When talking about the actors involved in policy-making, one respondent commented that policies used to be largely developed behind closed doors (by policy makers), but that the role of the public in policy-making has now expanded

> *"We listen to people's wishes. If signals come from the public, we try to respond to them. . . . Citizens have a large say in their residential environment. You see the same in other municipalities."* (M, spatial planning official.)

In this context, respondents also mentioned the benefits of working within a small municipality as follows: (1) officials from different policy sectors know each other and often work within a short physical distance from one another and thus have close social ties and physical proximity and (2) smaller municipalities were said to be more sensitive to the needs (including public health needs) of their citizens. One respondent referred to the occasional lack of opportunity to take these needs into account (e.g., in developing footpaths and safe crossings):

> *"If it does not work out that's usually due to money problems."* (M, sSpatial planning official.)

Organizational structures were said to hamper intersectoral collaboration since they are organized along sectoral lines. In practice, this meant that several sectors did not share a manager who would be responsible for more than one sector, and who could focus on the elements shared by the sectors. One official referred to the facilitative role of the change

that had taken place in the organizational structure of their municipal government (which became flatter as a result of departments being merged) and the effect this had had on the distance and collaboration between policy makers from different sectors:

> *"It's only recently, since we're housed together, that we hear each other's views. Until recently, we might write a policy plan here, while the people at spatial planning established a different policy plan that wasn't compatible at all. We're now trying to prevent that in the new department, but I do not even want to think about the way these things go in larger municipalities."* (Official for youth services, social services, and tourism.)

This official indicated that the bureaucracy in larger municipalities is widening the gaps between policy makers and thus raising the barriers to intersectoral collaboration.

When talking about the role of organizational structures, respondents also mentioned the difference in agenda-setting in the various policy domains. Organizational structure could lead to convergence or divergence of interests. One official referred to the lack of interest among the technically oriented sectors in maintaining a welfare institution. This hampered the achievement of welfare-oriented policy goals, since the technically oriented sectors were not interested in supporting such an institution:

> *"For instance when it's about the use of buildings, we from a welfare point of view think it's important that such a [welfare] institution continues to exist, but [the technically oriented departments] have other interests.* (Official for youth services, social services, and tourism.)

This also relates to the next barrier: budgets as well as responsibilities (and goals) tend to be allocated along sectoral lines and are also related to the relevant "cultural" differences between the various policy sectors:

> *"You also notice differences of opinion, especially differences in departmental cultures. For instance I'm also responsible for tourism, and from a tourist perspective I would have preferred a different option [referring to designing attractive sites for tourists], but we weren't involved at that stage. Well and by the time we were informed about it, everything had already been settled."* (F, official for youth services, social services, and tourism.)

Thus, each policy sector uses a different strategy to achieve their diverging goals. This divergence in policy goals makes it difficult to align strategies:

> *"When you look at the current plans, you cannot say we're specifically considering public health... We're not really trying to see whether we can actively, involving the built environment, playground equipment for kids and so on."* (M, spatial planning official.)

> *"It's just not that easy"* (F, spatial planning official.)

There are few opportunities to align policy strategies since less dominant policy departments are systematically being involved in the policy development cycle at too late stage. One respondent said that construction plans were usually first implemented, and his sector was then asked to repair the damage:

> *"I get the feeling that if social services had been involved in this at the first planning stage..."* (M, Public health official.)

> *"It would have been a completely different plan."* (F, official for youth services, social services, and tourism.)

> *"And would that be intentionally or unintentionally?"* (F, university researcher) *(both policy officials appear very uncomfortable because it is a sensitive topic.)*

Further barriers that decrease the opportunities to adjust policy plans to public health goals were said to be national standards or legislation, which might hamper the perceived ability to take health aspects into account, since they were sometimes either too strict or too loose. If those national guidelines were not strict, tightening them would improve public health outcomes; this was often difficult since it would affect economic performance or be impossible due to the budget cuts:

> *"There are a number of guidelines, and we try to stick to them ... as long as the budget allows it. ... I find that this year we cannot include any measures for the "sustainably safe" campaign [a concept in which neighborhoods are designed in such a way that they create environments promoting safe active transport] in the operational budget."* (M, transport department official.)

When non-health policy sectors are not sure of the influence their policy has on health, and they want to be advised on this, they have to pay to obtain such information from the regional Public Health Service:

> *"but if it [the question regarding public health advice] is not specific, we have to pay for it."* (M, municipal environment official.)

In addition to this, there are the budget cuts that municipal governments have had to introduce due to the economic crisis. Maintaining sports facilities requires large sums of money, which are currently difficult to make available. Also, the current neoliberal political climate aims to decrease government involvement in policies on community organizations (fewer regulations):

> *"At the moment, we're mostly trying to create the right conditions for sports facilities. ... We're*

> *not going to tell the clubs what to do [e.g., regulating the availability of healthy snacks in their canteens].*" (M, official for education, child care, sports, and cultural affairs.)

Although governments are less involved in using subsidies to control local organizations, a potential for imposing some controlling requirements was mentioned:

> "*We have a number of subsidy schemes [to improve public health] but we do not prescribe what they have to do, their policies. . . . But you could think about that, you could come to agreements with them, like for instance we want you to pay attention to such and such once a year [referring to various health topics].*, (F, official for youth services, social services, and tourism.)

Conservative local organizations (which are unwilling to pay attention to health aspects) can also hamper the implementation of an integrated approach:

> "*These clubs, they do not feel the need to organize after-school activities. They still have enough members. Like the idea of taking over gym classes; they do not feel the need.*" (M, official for education, child care, sports, and culture.)

The rigidity of organizations was also mentioned as a factor impeding collaboration. For example, even if management is in favor of collaboration, when those at the operational level do not want to change, it will take a long time before a school or sports clubs actually implement, for example, food policies that take health into account. Therefore, a lot of perseverance was said to be needed on the part of the health sector to get integrated public health policies implemented. Additionally, the commercial nature of most community organizations could reduce the opportunities to implement certain health policies because they might put them at a competitive disadvantage:

> "*The first thing people throw away is the greens [e.g., a piece of lettuce and a slice of tomato]. You just find it thrown away somewhere. So then you could say you should not sell fatty snacks, but then they're a commercial enterprise, they have to make a living.*" (M, official for education, child care, sports, and culture.)

4. Discussion

This study examined the resources that policy actors from non-health-related government sectors needed in order to collaborate with the health sector in developing integrated public health policies. Our interviews showed that six factors, divided over the three resources of motivation, capability, and opportunity, represented the most salient barriers to intersectoral collaboration. These resources are relevant for the development of integrated public health policies to prevent childhood obesity, but they are thought to be similar for "wicked" public health problems in general. The factors included specific discipline-related policy goals and territoriality (motivation), a disability to relate one's own work to public health and the failure of management to facilitate this (capability), and a lack of resources and inappropriate organizational structures (opportunity). Below, we present some recommendations for each of these resources, which may help to achieve a transformation of the current fragmented situation into one of integration.

4.1. Motivation to Collaborate: Bridging Gaps May Not Be as Difficult as It Seems. Firstly, there was little motivation among the non-health departments to collaborate with the health sector, since the non-health departments claimed to have different policy goals than public health. Their goals were related to their own policy discipline and thus hard to change. Each policy domain works on the basis of its own logic and without regard for the impact on other areas of society. Such "disciplinarity" was also found to hamper intersectoral collaboration in the study by Bovill [33]. The non-health sectors do not receive any incentives to collaborate with the health sectors, since they are judged (by management and municipal executives) on the basis of a set of criteria that are specific to their department. Nevertheless, when we asked respondents about the content of these "diverging" policy goals, we found that the goals of most non-health sectors were sometimes clearly related to public health goals, sometimes even to such an extent that they might easily be replaced by public health goals. For example, the Department of Transport said they were highly motivated to make their municipality very safe for cyclists, and that "promoting sustainable environments" was the essence of their work. A "sustainable environment," however, is almost identical to the public health goal of promoting a "leptogenic" environment, since both terms describe an environment in which citizens feel safe and encouraged to use active means of transport (i.e., cycling, walking). However, this link was overseen by both sectors, and bridging the gap between these disciplines, thus, seemed difficult, while in fact the bridge was already present (it only needed to be detected).

This barrier to collaboration might be overcome if public health professionals could reframe a health topic in such a way that it matches the terminology of the other policy sectors. Reframing health issues in terms understood by the non-health policy sectors can help remove the need to compete with those more dominant policy frames. Such re-framing is especially urgent for childhood obesity, as this is still described as a matter of individual responsibility, so that only a set of limited and mostly ineffective policy strategies to prevent childhood obesity come into view. Therefore, public health professionals need to put effort into understanding the goals and vocabulary of other relevant disciplines, in order to be able to re-frame the debate on childhood obesity in such a way that other policy domains will also realize the risk that childhood obesity poses for the achievement of their own policy goals (e.g., reduced economic performance due to obesity-related work absenteeism). As Stone stated: "*Nothing is a risk until it is judged to be a risk*" [53].

Secondly, the more welfare-oriented policy makers reported that territoriality was hampering intersectoral collaboration. This finding is also in line with the research findings reported by Bovill [33]. Territoriality was related to the different "world perspectives" in their different policy domains (i.e., their territories). It was remarkable that only those respondents who were working in policy fields perceived to be more closely related to the public health sector (e.g., youth services and sports) reported that the outlook of the more technically oriented policy sectors (e.g., spatial planning and transport) was fundamentally different from their own. According to them, the lack of visible results of health policies was a key distinctive feature explaining why the policy field could be divided into two "subcultures." Technical sectors focus on bricks and mortar (i.e., changing the physical environment), while welfare sectors focus on people (i.e., the subjective well-being of citizens). Measuring subjective well-being is clearly much harder than measuring physical changes. In the view of welfare-oriented policy makers, the technically oriented policy makers are stereotyping them as "talkers" rather than "doers." This attitude was, however, not explicitly confirmed by the statements of the more technically oriented policy makers themselves and thus might represent an unintentional preconception on the part of the welfare sector.

A way to overcome this territoriality problem is to make health outcomes more visible; increased understanding of each other's work may reduce the stereotyping currently experienced by welfare-oriented policy makers. Additionally, frequent communication can be expected to familiarize policy sectors with one another and increase trust "familiarity breeds trust", which was also mentioned to be an important facilitating factor for collaboration [54].

4.2. Capability to Collaborate: The Blind Leading the Blind. Since policy makers were not used to collaborating with policy sectors outside their own "niche," their experience of intersectoral collaboration was limited (see also [16, 17, 45]). Most respondents argued that it was "new" for them to think explicitly about public health outcomes in relation to their own work. Although they unconsciously paid attention to public health aspects, such decisions were not consciously made and thus not communicated explicitly to the health sectors. This finding is in line with those by Aarts et al. [23], who found that most policy sectors were in fact paying attention to public health, without being aware of it.

In line with the suggestions made by R. Axelsson and S. B. Axelsson [46], this barrier can be overcome by increased communication and stimulating joint planning. We recommend more explicit communication about the current (sometimes health-promoting) decisions of nonhealth sectors to increase awareness about the links between the health and non-health sectors. Regional Public Health Services can assist by highlighting the similarities between the work of both sectors. To this end, Public Health Services also need to expand their skills. In addition, sufficient joint planning would enable alignment of policy strategies. Mismatches, which were sometimes so pervasive that certain policy documents (in which much time and effort had been invested) had to be rejected completely, can be prevented through early alignment. One tool that can be used to explore more specific strategies to achieve such alignment is contribution mapping [55].

In this context, a fourth barrier was also identified: the failure of the heads of departments to stimulate intersectoral collaboration. Within hierarchical organizations, heads of departments manage the work processes that can lead to intersectoral collaboration, so their potential influence is large (at least in theory). One explanation for the lack of involvement of management might be that, as was found by Steenbakkers et al. [45], managers lack sufficient know-how for intersectoral collaboration. Managers could adopt an ambiguous attitude towards the pursuit of integration because they are aware of the demands this would impose on them. Moreover, their inexperience in this "new" job requirement might make them feel insecure about their own ability to do the job and thus create stress. Another cause of stress might be related to their fear of losing status: within hierarchical organizations, integration requires system-wide changes. Merging several departments requires changing organizational subcultures into one new organizational culture, and these cultural changes should be complemented by changes in the organizational structure to be sustainable. By making managers responsible for more than one sector, they might become more focused on the elements shared by the various sectors. However, this requires changes that can put the status of actors higher up in the hierarchy into question. The expectation of losing status might reduce the motivation among management and municipal executives more than among operational level actors (the higher in the hierarchy the more power they stand to lose). To keep the system as it is, higher level actors might therefore intentionally inhibit real changes (i.e., changes that might be truly effective for intersectoral collaboration). Previous studies [56] have identified that, within local governments, process management is insufficiently implemented and a more central role of "liaison" manager is warranted [57]. Intersectoral collaboration will be facilitated if top management supports intersectoral collaboration and heads of departments act as "champions" of such collaboration [33].

4.3. Opportunity to Collaborate: There Is No Such Thing as a Free Lunch. The fifth barrier that our study identified was that policy makers had insufficient resources to adjust their policy plans to public health; non-health sectors argued that paying attention to health requires time and money. Due to the budget cuts faced by most municipalities in the Netherlands, both resources are currently in short supply. Additionally, some policy makers argued that they would not approach the regional Public Health Services for advice, as they would have to pay for it.

This barrier might be overcome if the health policy sectors or the regional Public Health Service were involved in the development of policy plans at an earlier stage, which would help prevent damage having to be repaired afterwards.

Health professionals should invest efforts in making these preventable and long-term costs more proactively visible at an earlier stage of the policy cycle (e.g., by conducting health impact assessments [57]). If the regional Public Health Services could decide to offer their policy advice free of charge, the municipal departments might become more proactive in asking for advice, and the non-health sectors might more clearly understand the aims and added value of the intersectoral approach, which was found to be an important facilitator for intersectoral collaboration [33].

The sixth barrier we found was that organizational structures hampered intersectoral collaboration. Switching from a hierarchical to a "flatter" organizational structure [57] may result in policy sectors no longer working in a fragmented system, but being forced to work within intersectoral teams. A "divisionalized adhocracy" is expected to be more suitable for intersectoral collaboration [57], since complex and highly interdependent work fits in better with an organizational structure in which teamwork and liaison managers coordinate work processes, which is thus a prerequisite for the development of integrated public health policies. As Hunter [42] argues, the central feature of all attempts to develop partnerships involving whole systems, rather than individual "silos," is that they are superimposed on "*a fragmented and largely tribalistic set of arrangements characterized by different cultures and ways of conducting the business*." Thus, significantly better public health outcomes can be achieved by removing barriers such as sectoral budgets and different priorities and procedures in each sector [33], which can prevent the absorption of significant resources (time, money) that is currently caused by these fundamental errors of organizational structures that have endured for decades [42].

4.4. Strengths and Limitations. As with all single-case studies, the results of our study are difficult to generalize, as it involved one municipality and a limited number of governmental actors. In addition, the size of the municipality, which was very small, could also have an effect on the generalizability of our findings. However, most municipalities in the Netherlands are actually small or medium sized (<100,000 inhabitants) [58]. Possible aspects that might be related to the size of the municipality are the strength of social ties and physical proximity (knowing each other professionally and personally, working in the same office), responsibility for more than one policy sector (in smaller municipalities, public health officials are often responsible for one or two other policy sectors as well), the type and magnitude of problems that are encountered (typical urban problems versus local issues), the amount of resources available for public health (lack of resources may function as an incentive for collaboration, while lack of time acts as a discouragement), and the organizational structures (more or less bureaucratic). Another limitation might be the lack of triangulation (e.g., document analysis). A strong point of this study was that we achieved data saturation, and that representatives from all policy disciplines were involved. Another strong point of this study might be that the public health official and the university researcher reflected on each of the interviews together. This enabled the researcher to obtain a more accurate interpretation of the data than would otherwise (without the involvement of someone with background knowledge about the respondents) be possible. The member checks we conducted (a report of each interview was sent to the interviewee) presumably also increased the reliability of our data [59].

5. Conclusions

Our single-case-study has identified potentially important facilitators and barriers regarding intersectoral collaboration to promote public health in general. The resources we identified are also applicable to the development of specific integrated public health policies to prevent childhood obesity. This means that public health officials can use this information to anticipate barriers that might hamper intersectoral collaboration for childhood obesity prevention. The most promising facilitating factors we identified were related to motivation, while the least prominent barriers were related to capability, and the most pervasive barriers were related to opportunity. This means that although non-health sectors might be motivated to collaborate with the health sectors, more attention should be paid to the capabilities required, and to create opportunities for collaboration.

The influence of local government actors and their policies have so far largely been neglected in public health research. Hence, a large potential for developing health promoting policies and interventions by local government organizations still remains to be discovered. Investing in intersectoral collaboration might increase the effectiveness and sustainability of current health promotion efforts to prevent childhood obesity.

Appendix

Items in the Interview protocol

(1) Clarifying the role and influence of the policy sectors: their general policies and more specific policies, policy goals.

(2) Identifying interfaces between a particular policy sector and the public health sectors.

(3) Exploring to what degree a particular policy actor is aware of health aspects within their sector and of the extent to which they are used to collaborating with the regional Public Health Service or the public health department within their own organization.

(4) Investigating what the particular policy sector thinks about intersectoral collaboration with the health sector.

(5) Exploring opportunities for more collaboration between health and non-health policy sectors.

(6) Detecting barriers to attention for public health aspects in non-health policy sectors.

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Research Article

Indices of Abdominal Adiposity and Cardiorespiratory Fitness Test Performance in Middle-School Students

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Background. Previous research suggests that use of BMI as a screening tool to assess health in youth has limitations. Valid alternative measures to assess body composition are needed to accurately identify children who are aerobically fit, which is an indicator of health status. The purpose of this study was to examine the associations between select anthropometric measures and cardiorespiratory fitness test performance in middle-school students. *Methods*. Participants included 134 students (65 boys and 69 girls) recruited from the 6th, 7th, and 8th grades. Anthropometric measures consisted of BMI, waist circumference (WC), waist-to-height ratio (WHtR), and percent body fat estimated from two-site skinfolds (%BF-SKF), as well as the hand-held OMRON BIA device (%BF-BIA). Cardiorespiratory fitness tests included the one-mile run and PACER test. Data were collected on four separate testing days during the students' physical education classes. *Results*. There were statistically significant moderate correlations between the %BF estimations, WHtR, and cardiorespiratory fitness test scores in both genders ($P < .001$). BMI at best only displayed weak correlations with the cardiorespiratory fitness test scores. *Conclusions*. The results suggest that alternative measures such as %BF-SKF, %BF-BIA, and WHtR may be more valid indicators of youth aerobic fitness lending to their preferred use over BMI.

1. Introduction

The current pediatric obesity epidemic manifests concerns for adverse cardiovascular risk factors among overweight youth. However, Eisenmann et al. [1], using body mass index (BMI) as the marker of adiposity, found that youth in both the low- and high-BMI categories were associated with a more favorable cardiovascular disease (CVD) risk-factor profile than individuals whose BMIs were in the "healthy" range. This paradox leads to a significant issue in assessing health and fitness in youth when using BMI. Research has also suggested that along with body composition, aerobic fitness must also be considered to accurately assess health status in a population. Lee et al. [2] found that unfit lean men had a higher risk of cardiovascular disease and all-cause mortality than fit but overweight men. These findings suggest that fitness offers some protection against CVD risk even if the individual is overweight. Similar results have been reported for the female population [3]. Using skinfold thickness as the measure of body fatness and stratifying youth into high-fat/high-fitness, high-fat/low-fitness, low-fat/high-fitness, and low-fat/low-fitness groups, it was found that both fitness and fatness must be considered to assess CVD risk in the pediatric population [4]. Jago et al. [5] found that fitness and fatness influenced CVD risk, but body fatness was the stronger predictor of health risk in a sample consisting of 6th grade youth. Acknowledging that both body composition and cardiorespiratory fitness are both important in determining the health status of an individual, and that BMI may have inherent limitations that affect its validity as a marker of adiposity, a question must be addressed to determine what alternative body composition measures to BMI most strongly associate with cardiorespiratory fitness in the pediatric population.

Although it is used extensively in epidemiological research, BMI has its limitations. The most prominent is that it does not take into account lean body mass nor does it specify the degree of central adiposity [6], which has been linked to increased risks of chronic disease in boys and girls [7, 8]. Although BMI is commonly used and easy to calculate, it is

uncertain whether it is superior to other feasible measures of childhood body composition [9].

One alternative to BMI that has demonstrated utility in estimating body composition and chronic disease risk in youth is skinfold thickness assessment (SKF). The two-site SKF (tricep, calf) has yielded body fat estimates that have agreed closely with a four-component criterion measure of body fat in an independent sample of Caucasian and African American adolescents [10]. However, if used as the primary assessment in physical education or even in clinical settings, a child being tested may become uncomfortable due to the intrusive nature of the assessment (skin pinching). SKF is also time consuming; so, assessing a large number of children within a restricted time frame may be cumbersome for both physical educators and researchers alike.

Other feasible alternatives for body composition assessment include bioelectrical impedance analysis (BIA), waist circumference, and waist-to-height ratio. BIA has shown acceptable and reliable results when predicting percent body fat [11, 12]. Ihmels et al. [13] found that the Omron hand-held BIA device and the two-site SKF for assessing body composition produced agreeable results with each other. Another alternative body composition measure is waist circumference (WC). Bassali et al. [14] had shown that children with a WC above the 90th percentile are at higher risk for dyslipidemia and insulin resistance compared to obese children, as determined by BMI, with a normal WC. Another measure of central adiposity, waist-to-height ratio (WHtR), has the advantage of not requiring population-specific, age, and sex-specific reference tables contrary to WC [15]. In Mexican children aged 6–12 years, a WHtR cutoff of .59 demonstrated to be a strong predictor of metabolic syndrome, with values below .5 displaying poor sensitivity and specificity [16]. WHtR has also been shown to detect adverse CVD risk factors in normal weight children who are centrally obese [17]. In the US adult population, area under the curve (AUC) values, which are used to identify the accuracy of a test or measure's ability to classify individuals with or without a disease or condition, were higher for WHtR than all other anthropometric parameters in detecting cardiometabolic conditions in both women and men [18].

All of the aforementioned anthropometric measures have displayed varying degrees of association with health markers in the pediatric and adult populations. To our knowledge, no previous research has compared all of these measures' relationships to youth cardiorespiratory fitness, which has been linked to health status in both children and adults [19, 20]. Two primary components of physical fitness include cardiorespiratory fitness and muscular fitness; however, it is cardiorespiratory fitness that is more closely linked to health, specifically cardiometabolic health. Cardiorespiratory fitness, also called cardiovascular fitness, aerobic fitness, or aerobic capacity, is the overall capacity of the cardiovascular and respiratory systems to carry out prolonged exercise.

Two popular aerobic capacity fitness tests used in physical education settings include the one-mile run and the 20 m Progressive Aerobic Cardiovascular Endurance Run (PACER). Both of these field tests estimate aerobic capacity, which can be operationally defined as estimated maximal oxygen uptake or VO_2 max. To interpret the scores, the PACER test is converted to one-mile run times via the Primary Field Test Equating Method [21], which is then converted to estimated VO_2 max via the Cureton et al. [22] equation. Actual one-mile run times, a more direct assessment of aerobic capacity, are also converted to VO_2 max using this same equation. Welk et al. [23] demonstrated that aerobic fitness (VO_2 max) could be used to differentiate between American adolescents with and without metabolic syndrome. Mesa et al. [24] showed that higher levels of cardiorespiratory fitness are associated with a more favorable metabolic profile in both overweight and nonoverweight Spanish adolescents. Cardiorespiratory fitness has also been inversely associated with low-grade inflammatory markers [25].

Due to the associations between cardiorespiratory fitness and health, it is necessary to find relationships between anthropometric measures that estimate body composition with aerobic fitness test performance to more clearly understand what screening measures have utility identifying youth with inadequate cardiorespiratory fitness and consequent increased risk for chronic disease. Anthropometric measures that correlate most strongly to cardiorespiratory fitness can serve as proxy measures of health status for physical education specialists, school nurses, and clinicians to use in a variety of settings. Therefore, the primary purpose of this investigation was to examine the relationships between body composition estimated from select anthropometric measures and cardiorespiratory fitness in middle school students. The specific anthropometric measurements examined consisted of BMI, WC, WHtR, and percent body fat estimated from two-site skinfolds (%BF-SKF) and the Omron hand-BIA device (%BF-BIA). The one-mile run and PACER tests were used to assess cardiorespiratory fitness. It was hypothesized that measures of abdominal adiposity (WC and WHtR) and body fat percentage estimations (%BF-SKF and %BF-BIA) would have higher associations with cardiorespiratory fitness than BMI based on the previous research examining these parameters' relationships with health status in youth.

2. Methods

2.1. Participants. Participants included 134 school-aged youth (65 boys and 69 girls) recruited from the 6th, 7th, and 8th grades (mean age = 12.9 years, SD = .07 years) from three schools located in a metropolitan area in the Southwestern United States. The sample distribution by grade included 34 6th graders (17 boys and 17 girls), 52 7th graders (22 boys and 30 girls), and 48 8th graders (26 boys and 22 girls). Written consent was obtained from parents and assent was obtained from the participants prior to data collection. The University IRB and principals from the participating schools approved the protocols used in this study.

2.2. Procedures. All data collection took place during each student's physical education class on 4 separate testing days with at least 1 week separating testing sessions. All anthropometric and cardiorespiratory fitness assessments were conducted at least 2 hours postprandial during the final two class periods of the school day. A trained graduate

student within the Department of Exercise and Sport Science administered all anthropometric measures and fitness tests to ensure consistency during data collection. Body composition and anthropometric measures were administered on Day 1. Students were asked to remove their shoes, as height (to the nearest 1 cm) and weight (to the nearest 0.1 kg) were determined using a portable stadiometer (Seca 213; Chino, CA, USA) and medical scale (Tanita HD-314; Arlington Heights, IL, USA). Students then entered a private screening area where three abdominal circumference measurements were taken at the level of the superior border of the iliac crest on the participant's right side using a steel measuring tape. All measurements were estimated to the nearest 0.1 cm with the average of the three measures used as the participant's waist circumference. Skinfold measurements were taken on the students' tricep and calf using a Lange (Ann Arbor, MI, USA) skinfold caliper. Each site was measured 3 times in a rotating order on the students' right side with the average used as the recorded measure. Percent body fat was then estimated using the equations from Slaughter et al. [26]. Finally, the students' height, weight, age, and gender were entered into a handheld OMRON body fat analyzer (Model HBF-306; Lake Forest, IL, USA). The students then held the analyzer with arms extended, parallel to the floor until the device displayed the student's body fat percentage.

The 20 m PACER test was administered on Day 2. The PACER test was administered on a marked gymnasium floor with background music and cadence given by an audio CD. No more than 10 students participated in the assessment at any given time. Students' ran from one floor marker to another marker set 20 m apart while keeping pace with the prerecorded cadence. The test was terminated when a student twice failed to reach the opposite marker in the allotted time frame or when he/she voluntarily stopped. Day 3 consisted of the one-mile run test. The one-mile run was administered on either a standard track or measured flat trail on school grounds. No more than 10 students participated in the one-mile run at any time. Time was kept via a handheld stopwatch (Robic Oslo M427; Oxford, CT, USA). Finally, Day 4 served as the makeup day for those students who had not completed a test in Day 1 through Day 3.

2.3. Statistical Analysis. Data were screened for outliers and normality was checked prior to the main analyses. Comparisons among grade levels and between the genders on anthropometric measures and cardiorespiratory fitness test performance were examined using multiple 2×3 factorial ANOVA tests followed by Bonferroni post hoc analyses. Canonical correlations were used to examine linear weighted associations between the anthropometric multivariable dimension (BMI, WC, WHtR, %BF-SKF, and %BF-BIA) and the cardiorespiratory fitness multivariable dimension (PACER and one-mile run). Significantly correlated dimensions (or variates) were reported along with the Redundancy Index (Rd) for each significant canonical function, which was used as an estimate of the amount of shared variance between anthropometric dimension (independent variate) and the cardiorespiratory fitness dimension (dependent variate). Based on the practical significance of the Rd, the standardized coefficients, canonical loadings (the correlation between a measure and its variate), and canonical crossloadings (the correlation between a measure and the opposite variate) were reported. Pearson product-moment correlations were then employed to examine the associations among the specific anthropometric measures and between the anthropometric measures and cardiorespiratory fitness test scores within each gender group. BMI and age were then controlled for using partial correlations. Statistical significance was set at an alpha level of $P \leq .05$ and adjusted appropriately for ANOVA post hoc analysis. Data analyses were carried out using STATA v12.0 (College Station, TX, USA) statistical software.

3. Results

3.1. Grade and Gender Differences. Table 1 shows the means, standard deviations, grade, and gender effects for the anthropometric measures and cardiorespiratory fitness test scores per grade and gender group. A factorial ANOVA test revealed a significant grade effect for height ($F_{(2,128)} = 29.85$, $P < .001$) and weight ($F_{(2,128)} = 27.52$, $P < .001$). Students in grade 7 were significantly taller ($M = 1.63$ m, SD = .10 m) and heavier ($M = 49.7$ kg, SD = 10.0 kg) than students in grade 6 ($M = 1.52$ m, SD = .06 m, height; $M = 40.6$ kg, SD = 7.26 kg, weight) ($P < .01$), and students in grade 8 were significantly taller ($M = 1.66$ m, SD = .08 m) than students in grade 6 ($P < .01$), and significantly heavier ($M = 57.4$ kg, SD = 12.0 kg) than students in grade 7 and grade 6 ($P < .01$). There was also a significant grade effect for BMI ($F_{(2,128)} = 12.04$, $P < .001$) as BMI was higher in grade 8 ($M = 20.4$ kg/m^2, SD = 2.90 kg/m^2) compared to grade 7 ($M = 18.4$ kg/m^2, SD = 2.59 kg/m^2) and grade 6 ($M = 17.4$ kg/m^2, SD = 2.95 kg/m^2) ($P < .001$). A grade effect for WC ($F_{(2,128)} = 6.67$, $P < .001$) revealed that measurements were higher in grade 8 ($M = 70.0$ cm, SD = 8.27 cm) than grade 6 ($M = 63.5$ cm, SD = 6.13 cm) ($P < .001$) but not grade 7 ($M = 66.8$ cm, SD = 7.77 cm). There were no statistically significant differences among the grades in WHtR, %BF-SKF, or %BF-BIA. Regarding the cardiorespiratory fitness test scores, a grade effect for one-mile run times ($F_{(2,128)} = 9.85$, $P < .001$) revealed that grade 8 had significantly faster one-mile run times ($M = 447.7$ s, SD = 82.94 s) than grade 7 ($M = 451.2$ s, SD = 71.3 s) and grade 6 ($M = 485.5$ s, SD = 136.2 s) ($P < .01$); however, there were no differences among grades in PACER test performance.

Regarding the gender effects, boys in the sample were taller and heavier than girls ($P < .05$); however, there were no differences between the genders in BMI. Boys also displayed lower body fat percentages than girls when estimated from %BF-SKF and %BF-BIA ($P < .001$), but there were no statistically significant differences between the genders in WC or WHtR. Finally, regarding the cardiorespiratory fitness test scores, boys had statistically faster one-mile run times ($P < .001$) and higher PACER scores than girls ($P < .001$). There was no statistically significant grade by gender interactions.

3.2. Canonical Correlations. Table 2 depicts the two statistically significant canonical functions yielded between the anthropometric dimension (%BF-SKF, %BF-BIA, BMI, WC,

Table 1: Anthropometric measures and cardiorespiratory fitness scores per grade and gender group (means ± S.D.).

	Grade 6 (n = 34)	Grade 7 (n = 52)	Grade 8 (n = 48)	Girls (n = 69)	Boys (n = 65)
Anthropometric measures					
Height (m)	1.52 ± .066	**1.63 ± .104**[+]	**1.69 ± .085**[+]	1.59 ± .08	**1.64 ± .12**[*]
Weight (kg)	40.6 ± 7.26	49.7 ± 10.0	**60.9 ± 12.8**[+]	47.78 ± 9.92	**52.69 ± 13.60**[*]
BMI (kg/m^2)[1]	17.4 ± 2.95	18.4 ± 2.59	**21.0 ± 3.07**[+]	18.69 ± 2.87	19.18 ± 3.21
% Body fat (SKF)[2]	20.7 ± 6.95	20.3 ± 6.64	21.3 ± 9.05	23.35 ± 5.99	**19.30 ± 7.85**[*]
% Body fat (BIA)[3]	21.7 ± 6.52	19.2 ± 5.89	19.2 ± 19.2	22.08 ± 5.09	**18.38 ± 6.84**[*]
WC (cm)[4]	63.5 ± 6.13	66.8 ± 7.77	**72.8 ± 8.27**[+]	65.89 ± 7.91	68.46 ± 8.10
WHtR[5]	.416 ± .042	.409 ± .045	.429 ± .039	.413 ± .045	.415 ± .041
Cardiorespiratory fitness scores					
One mile time (s)	561.0 ± 145.7	522.1 ± 142.8	**426.7 ± 91.34**[+]	557.2 ± 139.0	**450.4 ± 100.6**[*]
PACER (laps)	50.0 ± 19.3	49.2 ± 21.4	65.5 ± 26.1	44.79 ± 18.60	**60.4 ± 23.04**[*]

[1] BMI stands for Body Mass Index.
[2] SKF stands for % body fat estimation from the two-site skinfold method and Slaughter formula.
[3] BIA stands for % body fat estimation from the Omron BIA device.
[4] WC stands for waist circumference.
[5] WHtR stands for waist-to-height ratio.
[+] Grade effect, $P < .05$.
[*] Gender effect, $P < .05$.

Table 2: Canonical correlations.

Canonical correlation	Wilks' lambda	Degrees of freedom 1	Degrees of freedom 2	F statistic	Significance
.695	.4649	10	254	11.85	$P < .001$
.317	.8993	4	128	3.580	$P < .001$

and WHtR) and the cardiorespiratory fitness dimension (one-mile run and PACER). The first canonical function had a coefficient of $R_c = .695$, $P < .001$, and the second canonical function had a coefficient of $R_c = .317$, $P < .001$. The Rd for the first canonical function was Rd = .373, or 37.3% of shared variance; the Rd for the second significant canonical function was Rd = .0227, or 2.27% of shared variance. Because the first canonical function explained a significantly greater amount of shared variance between the two variates, it was the only canonical function justified for further analysis and interpretation. Table 3 shows the raw and standardized coefficients, canonical loadings, and canonical crossloadings for each measure for the first canonical function. The first canonical correlation shows that WHtR had the highest standardized coefficient in the anthropometric dimension (.797) with %BF-SKF, %BF-BIA, and WHtR having the three strongest canonical loadings (.747, .817, and .603, resp.) and crossloadings (.519, .568, and .419, resp.). The one-mile run had the highest standardized coefficient (.734), highest canonical loading (.951), and highest cross loading (.661) in the cardiorespiratory fitness dimension. These results suggest that the anthropometric and cardiorespiratory fitness dimensions do indeed correlate strongly with one another, with %BF-SKF, %BF-BIA, and WHtR measures significantly associating with the anthropometric and cardiorespiratory fitness dimensions.

3.3. Pearson and Partial Correlations. Tables 4 and 5 display the Pearson correlation matrices for all anthropometric measures and cardiorespiratory fitness scores for girls and boys, respectively. All anthropometric measures significantly associated with each other in both genders yielding moderate to moderately high correlations among the parameters ($P < .001$). One-mile run times correlated significantly with PACER scores for both boys ($r = -.655$, $P < .001$) and girls ($r = -.415$, $P < .001$). These inverse correlations suggest that faster one-mile run times were associated with higher PACER scores (an increase in performance), and vice-versa. %BF-SKF, %BF-BIA, and WHtR significantly correlated with one-mile run times in both genders ($P < .001$) yielding similar magnitude "moderate" correlations. WC only correlated significantly with one-mile times in girls ($r = .412$, $P < .001$). Likewise, BMI only significantly correlated with one-mile run times in girls ($r = .280$, $P < .05$). The direct (positive) correlations suggest that higher anthropometric measures were associated with slower one-mile run times (a decrease in performance), and vice-versa. In general, the anthropometric measures correlated less strongly to PACER scores than the one-mile times. In boys, PACER scores only significantly correlated with %BF-SKF ($r = -.440$, $P < .001$) and with %BF-BIA ($r = -.477$, $P < .001$). In girls PACER scores correlated with %BF-SKF ($r = -.315$, $P < .001$), %BF-BIA ($r = -.288$, $P < .05$), WC ($r = -.262$, $P < .05$), and WHtR ($r = -.305$, $P < .05$). The inverse (negative) correlations suggest that higher anthropometric measurements were associated with lower PACER scores (a decrease in performance), and vice-versa. Using partial correlations to control for BMI and age (Table 6), similar correlations were found between the

Table 3: Canonical coefficients and loadings for first canonical function.

	First canonical function				
	Raw canonical coefficient	Significance	Standardized canonical coefficient	Canonical loading	Canonical cross-loading
Anthropometric dimension					
BMI[1]	−.177	$P < .001$	−.540	.224	.155
BF-SKF[2]	.063	$P < .001$	.454	.747	.519
BF-BIA[3]	.079	$P < .001$	.497	.817	.568
WC[4]	−.127	$P = .05$	−.404	.258	.179
WHtR[5]	18.52	$P < .001$	.797	.603	.419
Cardiorespiratory fitness dimension					
One-mile time	−.017	$P < .001$	.734	.951	.661
PACER	.005	$P < .001$	−.374	−.800	−.556

[1]BMI stands for Body Mass Index.
[2]SKF stands for % body fat estimation from the two-site skinfold method and Slaughter formula.
[3]BIA stands for % body fat estimation from the Omron BIA device.
[4]WC stands for waist circumference.
[5]WHtR stands for waist-to-height ratio

Table 4: Correlation matrix showing anthropometric measures and cardiorespiratory fitness scores for girls.

	BMI	%BF (SKF)	%BF (BIA)	WC	WHtR	One-mile time	PACER score
BMI[1]	1						
%BF (SKF)[2]	**.651****	1					
%BF (BIA)[3]	**.604****	**.583****	1				
WC[4]	**.755****	**.559****	**.475****	1			
WHtR[5]	**.708****	**.530****	**.573****	**.889****	1		
One-mile time	**.280***	**.412****	**.400****	**.412****	**.583****	**1**	
PACER	−.194	**−.315****	**−.288***	**−.262***	**−.305***	**−.415****	**1**

[1]BMI stands for Body Mass Index.
[2]SKF stands for %body fat estimation from the two-site skinfold method and Slaughter formula.
[3]BIA stands for %body fat estimation from the Omron BIA device.
[4]WC stands for waist circumference.
[5]WHtR stands for waist-to-height ratio.
*$P < .05$.
**$P < .001$.

Table 5: Correlation matrix showing anthropometric measures and cardiorespiratory fitness scores for boys.

	BMI	%BF (SKF)	%BF (BIA)	WC	WHtR	One-mile time	PACER score
BMI[1]	1						
%BF (SKF)[2]	**.612****	1					
%BF (BIA)[3]	**.561****	**.762****	1				
WC[4]	**.820****	**.522****	**.523****	1			
WHtR[5]	**.707****	**.625****	**.632****	**.803****	1		
One-mile time	.199	**.449****	**.606****	.203	**.431****	**1**	
PACER	−.004	**−.440****	**−.477****	−.032	−.153	**−.655****	1

[1]BMI stands for Body Mass Index.
[2]SKF stands for %body fat estimation from the two-site skinfold method and Slaughter formula.
[3]BIA stands for %body fat estimation from the Omron BIA device.
[4]WC stands for waist circumference.
[5]WHtR stands for waist-to-height ratio.
*$P < .05$.
**$P < .001$.

Table 6: Partial correlations controlling for BMI and age.

	One-mile time		PACER	
	Boys	Girls	Boys	Girls
% BF (SKF)[1]	**.393****	**.316***	**−.542****	**−.262***
% BF (BIA)[2]	**.549****	.164	**−.539****	−.196
WC[3]	.146	**.328***	.034	−.170
WHtR[4]	**.412****	**.470****	−.202	**−.241***

[1] SKF stands for % body fat estimation from the two-site skinfold method and Slaughter formula.
[2] BIA stands for % body fat estimation from the Omron BIA device.
[3] WC stands for waist circumference.
[4] WHtR stands for waist-to-height ratio.
* $P < .05$.
** $P < .001$.

anthropometric measures and cardiorespiratory fitness test scores in both genders, with BMI and age seemingly having little confounding effect on the relationships.

4. Discussion

The primary aim of this study was to examine the associations between anthropometric measurements and cardiorespiratory fitness test performance in middle-school students. Results from the canonical correlation analysis suggest that there was a moderate to strong relationship between the anthropometric dimension and the cardiorespiratory fitness dimension. %BF-SKF and %BF-BIA along with WHtR had the strongest associations with the anthropometric dimension and the cardiorespiratory fitness dimension in this sample. Pearson product moment correlations indicated that %BF-SKF and %BF-BIA had moderate associations with one-mile run and PACER scores in both genders. WHtR had moderate associations with one-mile run in both genders and a significant association with PACER scores in girls. WC had statistically significant associations with one-mile run and PACER in girls, and BMI only had a statistically significant association with the one-mile run in girls. After controlling for BMI and age in this sample, most of the aforementioned significant correlations held, with BMI and age seemingly having little confounding effect on the relationships between anthropometric measures and cardiorespiratory fitness test scores.

In general, the differences among the grades and between the genders were consistent with previous research where cardiorespiratory fitness test scores improved at higher grade levels, boys showing lower mean body fat percentages than girls, and boys performing better on tests of cardiorespiratory fitness [27]. WC measurements were higher in boys compared to girls, despite having overall lower body fat percentages, but the differences between the genders were statistically nonsignificant. A higher mean WC in boys may be due to body fat deposits tending to accumulate in the abdominal region in males as opposed to the hips and buttocks as it tends to do in females during physical maturation [28, 29]. Paradoxically, however, WC and WHtR had the strongest associations with the cardiorespiratory fitness test scores in girls as opposed to boys, where body fat estimations had the highest associations with cardiorespiratory fitness. One possible explanation for this is the higher amount of lean body mass that tends to accumulate in boys during adolescence. A WC measurement does not distinguish between central adiposity and muscle (lean body mass); therefore, males with higher muscle mass may have an increased WC measurements not entirely due to fat accumulation but rather at least partially due muscular core development. Despite this possible limitation of WC, the correlations between WHtR were stronger than BMI across the cardiorespiratory fitness scores in both genders, displaying similar associations with the fitness scores as the associations between the body fat measurements and fitness. WHtR is useful because it takes into account an individual's height when estimating central adiposity. This is an important consideration because as children progress through development and into adulthood, bone structure changes make WC a less useful tool when comparing potential health risk between subjects. One student may be early in his or her development yet have a WC measurement similar to a peer who is taller, more physically developed, and in better physical condition. In this situation, the WC would be a less valid tool because of the height and physical development contrasts between subjects. One way to account for this is using age-gender reference tables; however, WHtR may provide a simpler index for interpretation purposes. The correction for height that WHtR takes into account would suggest that the taller individual would have less of a risk of cardiometabolic disease than the shorter individual with the same waist circumference based on previous research [30]. The results of this study support the evidence that WHtR may be a more useful indicator of cardiorespiratory fitness yielding stronger correlations with the cardiorespiratory fitness test scores than WC in both girls and boys.

The associations between cardiorespiratory fitness and health, specifically cardiovascular health, have been established in the literature, and body composition has also shown associations with health in both children and adults [31–33]. The canonical correlation analysis in this study supports that the anthropometric dimension, which comprises measures that estimate body composition, had moderate to strong correlations with the cardiorespiratory fitness dimension in the first canonical function. Within the anthropometric dimension, WHtR, %BF-SKF, and %BF-BIA had the highest standardized coefficients, canonical loadings, and cross-loadings. Canonical correlations maximize the associations between two dimensions or variates, which are a weighted linear combination of variables. Results from this analysis show that WHtR, %BF-SKF, and %BF-BIA had the strongest associations with both the anthropometric dimension and the fitness dimension. WC and BMI had weaker standardized coefficients and loadings in the model compared to the other aforementioned measures. This may suggest that BMI and WC may provide a less useful indicator of overall body composition than the other measures in the dimension. As stated previously, BMI limitations include that it does not account for lean body mass in an individual nor does it specify fat distribution. WC's major limitation is that it does not take into consideration height or bone structure, which makes comparisons between individuals difficult when identifying

health risk. %BF-SKF, %BF-BIA, and WHtR take these aforementioned limitations into account, which is reflected by their stronger associations with cardiorespiratory fitness test performance in this sample.

This study manifests some practical implications that must be considered for professionals who assess health and cardiorespiratory fitness in youth. Due to the stronger associations that body fat estimated from %BF-SKF, %BF-BIA, and WHtR had with the cardiorespiratory fitness scores compared to BMI, these measures may be preferable to BMI when attempting to identify children with less than adequate physical fitness. Administering the two-site SKF assessment to estimate body fat, although it is a better indicator of overall body fatness than BMI, can be cumbersome especially if used in a physical education setting for a large group of children. SKF may also make certain children feel uncomfortable during the assessment due to skin pinching. BIA certainly provides an alternative to the two-site skinfold for the estimation of body fat. However, research is conflicting on the agreement between these two methods in different populations of youth [34]. BIA, although useful for describing body composition in groups, its %BF estimates have large errors in individuals being influenced by factors such as nutritional and hydrational status [27]. WHtR offers an alternative to both these methods. Although it is not as direct of a method to approximate overall body fatness, WHtR estimates an individual's central adiposity relative to their height. Central adiposity has been associated with higher risk of chronic disease than overall body fatness in children and adults. The results from this study suggest that WHtR moderately associates with cardiorespiratory fitness in middle school-students. WHtR is also easy to administer, as all one needs is a standard tape measure and the height of the individual. And unlike WC, WHtR may not need age-gender reference tables for interpretation once a standard has been established for a population. Using this index can be used in clinical settings in attempting to identify children who are at higher risk for developing chronic disease. In physical education class, it could be used as an alternative to BMI throughout the school year for body composition assessment, or to assess the effectiveness of various curricula or interventions aimed at improving the health status of a class. Only 37% of states require some form of assessment in physical education, and of those that do, only 74% require assessment of physical fitness [35]. For those significant number of schools in the US that do not have some form of physical education body composition assessment, the WHtR index provides a valid, efficient, and easy-to-use measure for school nurses and health specialists to assess health of their respective student population outside of physical education.

There are limitations of this study that affect the generalizability of the results. The sample consisted of students in the 6th, 7th, and 8th grades from institutions where the racial distribution was heavily Caucasian (sample was approximately 85% Non-Hispanic Caucasian). Future research needs to examine the anthropometric associations with cardiorespiratory fitness test performance in all age groups and from a more ethnically diverse sample of children. Also, approximately 24% of the sample was classified as overweight/obese by FITNESSGRAM's body composition standards [36]. Future research may need a better representation of overweight/obese children when examining the associations in this study. Finally, WHtR currently has no established standards for US children in any age group, unlike BMI and body fat percentage. Future research may consider the findings of this investigation to inspire a larger scale study to set criterion referenced standards for WHtR to provide meaning to the interpretation of this index.

In conclusion, body fat estimated from the two-site SKF and the hand-held Omron BIA device, as well as WHtR, had moderate associations with cardiorespiratory fitness in middle-school students. BMI and WC had weaker associations with cardiorespiratory fitness test performance. The results of this study suggest that estimating body fat from either SKF or BIA, or accounting for height when measuring waist circumference (WHtR), may offer more valid alternatives to BMI and WC when trying to identify children that have less than adequate cardiorespiratory fitness, a strong indicator of health status. Future research needs to further explore these associations on different populations of children to establish screening measures that most accurately identify children at risk for chronic disease.

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Research Article

Organized Sports, Overweight, and Physical Fitness in Primary School Children in Germany

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Physical inactivity is associated with poor physical fitness and increased body weight. This study examined the relationship between participation in organized sports and overweight as well as physical fitness in primary school children in southern Germany. Height, weight, and various components of physical fitness were measured in 995 children (7.6 ± 0.4 years). Sports participation and confounding variables such as migration background, parental education, parental body weight, and parental sports participation were assessed via parent questionnaire. Multiple logistic regression as well as multivariate analysis of covariance (MANCOVA) was used to determine associations between physical fitness, participation in organized sports, and body weight. Participation in organized sports less than once a week was prevalent in 29.2%, once or twice in 60.2%, and more often in 10.6% of the children. Overweight was found in 12.4% of the children. Children participating in organized sports more than once per week displayed higher physical fitness and were less likely to be overweight (OR = 0.52, $P < 0.01$). Even though causality cannot be established, the facilitation of participation in organized sports may be a crucial aspect in public health efforts addressing the growing problems associated with overweight and obesity.

1. Introduction

In most industrialized countries, including Germany, the prevalence of overweight and obesity in children and adolescents has increased over the last decades [1–3]. This has also led to the occurrence of various metabolic or cardiovascular disease risks, previously only observed in adults [4, 5]. In addition to higher risks for cardiovascular disease and type II diabetes, increased body weight has been associated with psychosocial problems such as depression or low self-esteem [6] and decreased overall quality of life [7]. As excessive body weight tracks into adulthood and increases the risk for CVD, diabetes, or cancer [8, 9], childhood overweight has also been associated with premature mortality [10–12]. Overweight or obesity is a complex phenotype but various risk factors such as low levels of physical activity (PA) and increased sedentary behavior [13], parental obesity and activity levels [14, 15], or socioeconomic status [16] have been identified.

Along with the change in body composition a secular decline in physical fitness and motor ability in children has been observed [17–19]. The decline was most pronounced for aerobic fitness [20], which is associated with reduced CVD risk [21, 22]. A commonly discussed reason for the decline in physical fitness is low levels of moderate-to-vigorous physical activity [23, 24]. Specifically a decline in habitual physical activity including active transport has been observed [25, 26]. On the other hand participation in organized sports was maintained or even increased [27, 28]. In Germany, 70.2% of 7- to 10-year-old children are involved in sports clubs [29]. This number also reflects the importance of sports clubs concerning social integration and development of the personality [30, 31] in addition to physical fitness and health.

Due to its popularity, sports participation should be considered as an effective strategy to reduce fatness and increase fitness in children [32–34]. The World Health Organisation (WHO) also promotes the use of existing settings based on the national situation and cultural habits for the prevention of overweight and obesity [35].

While an inverse relationship between body composition and extracurricular sports participation was shown in adolescents [34], no such relationship was shown in primary school children [36]. Quinto Romani [37] concludes that the literature examining the effects of organized sports on children's weight status or physical fitness is inconclusive. In addition to problems of accurate assessment, sports participation in organized youth sports does not necessarily guarantee sufficient physical activity to achieve health benefits or increase fitness [38]. Further, various environmental factors need to be considered when examining the effect of sports participation on body composition and fitness. The purpose of the study, therefore, was to examine the association between participation in organized sports and physical fitness as well as overweight in 8-year-old children while considering various environmental constraints.

2. Materials and Methods

2.1. Subjects. Baseline data from 1119 (53% male, 47% female) second-grade children (7.6 ± 0.4 years) from 32 schools (64 classes) participating in a health and lifestyle intervention project (URMEL-ICE) in southwest Germany was used. The study protocol was approved by the institutional ethics review board, and parental consent as well as child assent was obtained prior to data collection.

2.2. Anthropometry. Height and weight were measured in 1064 children (95% of the total sample) according to standard procedures during a physical examination performed by the outpatient clinic of the Children's hospital. Height was measured to the nearest 0.1 cm (Ulm stadiometer, Busse, Ulm, Germany) and weight to the nearest 0.1 kg using a calibrated balance beam scale (Seca, Hamburg, Germany) with participants wearing only underwear. Body mass index (BMI) was calculated (kg/m^2) and converted to BMI percentiles (BMIPCT) using Kromeyer-Hauschild et al. [39] reference values. Overweight was defined as BMIPCT ≥ 90 [39].

2.3. Physical Fitness. The "Allgemeiner sportmotorischer Test für Kinder (AST)" (general motor abilities test for children) [40], a commonly used fitness test for 6- to 11-year-old children, was administered in the schools by trained personnel. In addition to the 6 items of the AST (6 min run, 20 m sprint, medicine ball throw, throw-on-target, throw-and-turn, and obstacle run) sit-and-reach test and one-leg-balancing from the Eurofit test [41] were incorporated to cover a wider range of fitness-related parameters. A total of 995 children (89% of all participating children) participated in these physical fitness tests.

2.4. Sports Participation. A parental questionnaire was used to determine participation in organized sports outside the school setting. As there is currently no validated instrument for the assessment of health behaviour available in German, questions were based on the KiGGS survey, which assessed health behaviour in 18,000 German children and adolescents [42]. Children's sports participation was classified as less than once a week, once or twice a week, and more than twice a week.

2.5. Confounding Variables. In addition, the questionnaire assessed confounding variables such as migration background, parental education, parental overweight and parental participation in organized sports. Confounding variables were dichotomized. Migration background was present when either the child's father or mother was born outside Germany or when a foreign language was spoken during the child's first years. Level of parents' education was differentiated by 10 years of schooling of either father or mother. A BMI cutpoint of 25 was used to determine between overweight and nonoverweight, and parental sports participation was separated by participation in organized sports or visiting a fitness centre more than one hour per week.

2.6. Statistical Analysis. Descriptive statistics for the three sports participation groups were calculated and checked for normal distribution. The odds ratio for children being overweight as well as sports participation was calculated via multiple stepwise logistic regression entering sex, overweight, migration background, level of parents' education, parental overweight, and parental participation in sports as confounding variables. In addition, the child's weight status was considered for the sports participation model, while sports participation was considered when calculating the odds ratio for being overweight. Differences in individual fitness parameters by sports participation were calculated via multivariate analysis of covariance (MANCOVA), again adjusting for the previously mentioned confounding variables. Bonferroni adjustment was used for post hoc analyses in case of significant group differences. Missing values were excluded per case, and level of significance was defined as $P < 0.05$. All statistics were calculated in SPSS (17.0.0).

3. Results

Table 1 shows age and anthropometric data of the total sample by sports participation. The majority of children (60%) participated in sports once or twice per week beyond the recommended 3 classes of PE. BMIPCT differed significantly between sports participation groups (F (2, 1004) = 6.81, $P <$ 0.01). Specifically, those reporting sports participation 1-2 times per week had significantly lower BMIPCT than those reporting less than once a week.

Table 2 displays the prevalence of potential confounding variables on child's sports participation. After entering all of these variables as well as sex in a multiple stepwise logistic regression, comparing children who participate less than once with those participating regularly in organized sports, only migration background as well as parental weight status remained in the final model, which explained between 11.2%

Table 1: Subjects characteristics of the total sample (all) stratified by participation in organized sports per week. Values are mean and SD.

N (% male)	All 1053 (53.5%)	Children's participation in organized sports per week		
		Less than once 307 (47.6%)	1-2 times 634 (54.9%)	More often 112 (61.6%)
Age (years)	7.6 (0.5)	7.6 (0.4)	7.5 (0.5)	7.6 (0.4)
Height (cm)	127.1 (5.6)	127.2 (5.5)	127.1 (5.6)	127.2 (6.0)
Weight (kg)	26.4 (5.0)	27.3 (5.6)	26.0 (4.7)	26.2 (4.9)
BMIPCT	49.9 (28.8)	55.1 (30.5)	47.6 (28.1)	49.0 (25.8)

Table 2: Distribution of the occurrence of confounding variables of the total sample (all) stratified by participation in organized sports per week. Indicated are *N* and %.

	All *N* (%)	Children's participation in organized sports per week		
		Less than once *N* (%)	1-2 times *N* (%)	More often *N* (%)
Overweight	124 (12.4)	56 (19.5)	61 (10.0)	7 (6.6)
Parental education ≤ 10 y	569 (57.3)	198 (70.7)	314 (52.0)	57 (52.3)
Migration background	259 (26.1)	137 (50.0)	102 (16.7)	20 (18.5)
Maternal overweight	341 (33.4)	131 (44.4)	178 (28.8)	32 (29.4)
Paternal overweight	573 (58.6)	171 (62.4)	338 (56.6)	64 (59.8)
Maternal organized sport	285 (27.5)	40 (13.2)	119 (31.9)	46 (41.8)
Paternal organized sport	272 (27.7)	47 (17.1)	192 (32.4)	32 (29.1)

Table 3: Odds ratio (OR) for overweight by participation in organized sports based on logistic regression adjusted for migration and parental weight status.

Participation in organized sports	Overweight (logistic regression)			
	OR	95 % confidence interval		*P*
Once or twice	0.522	0.327	0.834	0.007
More often	0.312	0.126	0.773	0.012

(Cox and Snell R^2) and 16.4% (Nagelkerke R^2) of the variance in sports participation. Having a migration background or overweight parents reduced the odds for regular sports participation. It was further shown that the odds of children being overweight were significantly lower with increased sports participation (Table 3).

Using MANCOVA, controlling for sex, overweight, migration background, parental overweight, and parental participation in organized sport, a significant main effect of participation in organized sports on most physical fitness parameters was shown (Table 4). Post hoc analysis using Bonferroni adjustment revealed that children who participate less than once a week in organized sports performed significantly worse than those who participate regularly. There were no differences between children participating once or twice per week in organized sports compared to those participating more often. No significant differences occurred for the 20 m sprint and obstacle run, even though there was a tendency of a better performance with higher sports participation. No association between sports participation and ball aiming was shown.

4. Discussion

In the present study 12.4% of children were overweight or obese, which is comparable to previously reported percentages in Germany and other European countries [43–45]. Similarly, participation rates in organized sports are comparable to those reported previously in German children [29]. The inverse relationship between fitness and overweight as well as physical activity and overweight has generally been accepted [46]. This study, however, further shows that this association remains even after controlling for various family-related confounding variables. These results suggest that sports participation is an important aspect when examining overweight and physical fitness, even at a relatively young age. Regular participation in organized sports, even only once or twice per week, already reduced the odds for being overweight by almost 50%. Similar results have been reported in adolescents [37, 47], 10- to 11-year-old children [48], and in preschoolers [3]. Interestingly, no association between sports participation and body fatness was observed in studies examining similar age groups [36, 49]. One explanation for these results may be that BMI does not necessarily differentiate between body fat and lean tissue. A lower amount of body fat in children with higher sports participation could be masked by a higher lean body mass, which would result in no differences in BMI. Zahner et al. [36], however, relied on skinfold measurements rather than BMI but could not show any association between BMI and sports participation either. These authors argue that engagement in organized sport may not necessarily reflect intensity. Further, only limited information on the type of sports children are engaging in is available, and different sports may affect body composition differently. In addition,

Table 4: Mean values and SD for individual fitness tests by participation in organized sports. *F* and *P* values are from MANCOVA.

	Children's participation in organized sports per week			MANCOVA	
	Less than once	1-2 times	More often	*F*	*P*
20 m sprint (s)	4.99 (0.48)	4.83 (0.41)	4.74 (0.42)	2.370	0.092
Sit and reach (cm)	0.56 (6.52)	2.14 (5.95)	3.00 (5.66)	6.841	0.001*
Medicine ball shot put (cm)	277.53 (69.47)	294.17 (63.27)	305.23 (60.57)	5.723	0.003*
6 min endurance run (m)	800.64 (123.16)	866.47 (138.86)	897.37 (124.57)	5.504	0.004*
Obstacle run (s)	25.21 (4.49)	23.71 (4.57)	22.96 (4.07)	2.555	0.078
Throw-and-turn (points)	13.43 (10.46)	16.58 (11.25)	19.57 (11.52)	4.120	0.017*
Ball aiming (points)	7.75 (3.78)	8.21 (4.19)	9.23 (4.31)	0.928	0.396
One leg balancing (points)	1.02 (0.57)	0.84 (0.57)	0.81 (0.62)	3.585	0.028*

*Difference between less than once a week and weekly sports participation.

sports participation is only one component of children's physical activity, and especially younger children probably obtain the majority of their physical activity via free play [50], which may also differ significantly in intensity. Nevertheless, engagement in organized sports has been associated with long-term engagement in physical activity [51]. The present study also indicates that migration status as well as parental weight status needs to be considered when examining the association between sports participation and body weight in children. Parental overweight as well as lower socioeconomic status has been shown to be associated with a higher body weight in children [52]. Migration status is also commonly associated with lower socioeconomic status [53] but a recent study in a German sample showed an inverse relationship between migration status and sports participation independent of household income or parental education [16]. This could be due to different cultural values and attitudes towards sports. Even though migration status is associated with educational level, no significant association between parental education and overweight in children was observed in the present study. Van der Horst et al. [54] also argued that parental support, such as transportation to training and competition, is a crucial component concerning children's sports participation. This kind of support seems to be more important than parents serving as role models, but more active parents are probably more likely to provide transportation or other forms of support for their children [55].

In addition, a significant relationship between sports participation and various components of physical fitness has been shown, independent of migration background, parental education, and parental sports participation. Particularly the role of regular sports participation in aerobic fitness should be emphasized as the inverse association between aerobic fitness and cardiovascular disease risk has already been reported in children [56]. Regular sports participation also increases power, flexibility, and balance [36, 57]. The better performance in these components may be crucial for continued engagement in sports and physical activity, as a better overall fitness allows for better performance and thus increases long-term motivation. Interestingly, Saar and Jürimäe [48] showed such an association between sports participation and fitness only in adolescents, but not in children. In this study, however, only endurance and flexibility were assessed. It should also be considered that younger children generally display lower engagement in organized sports [36] and obtain most of their exercise via unstructured play [50]. Bürgi et al. [58] argue that especially participation in vigorous activity increases physical fitness, but such activities can occur in unstructured play or general physical activity as well. Further, it could be argued that a prolonged engagement in sports is necessary to cause changes in physical fitness, and particularly in younger children, some may have just started participating in organised sports and, therefore, might not display any adjustments.

It should also be considered that the directionality of the relationship between regular sports participation and physical fitness cannot be determined via a cross-sectional study. It may be possible that children with a higher physical fitness are more likely to participate in organized sports due to their better abilities. Similarly, it remains to be determined whether increased body weight is a result of a lack of sports participation or whether selection bias leads to a lower participation of overweight children in organized sports. Most likely the association between sports participation and physical fitness as well as body composition is bidirectional, which will make it difficult to establish a causal pathway even in longitudinal studies. Nevertheless, it has been argued that participation in sports is one way to increase fitness and reduce body fat [33, 59] even though biological and genetic aspects need to be considered.

In addition to the cross-sectional design other limitations of the present study should be addressed. Relying on parent questionnaires for children's participation in organized sports may have introduced potential bias, particularly as parents were informed about the intention of the study due to the following intervention. There is also no information on the intensity children experienced during training sessions or the duration of their training. In general, however, training in organized sports at this age lasts between 60 and 90 minutes per day. Further, only participation in organized sports was considered rather than total physical activity, which may be problematic, especially in younger children. Ebenegger et al. [60], however, did show a direct relationship between sports participation and habitual PA in preschoolers. The large sample size, on the other hand, is a strength of

the present study, and an analysis of missing value did not show any systematic bias. In addition, anthropometric as well as physical fitness measurements were performed by trained staff and followed standard procedures, which adds to the credibility of the study.

5. Conclusions

Overall, the present study shows that increased participation in organized sports is associated with increased physical fitness and lower risk for overweight in elementary school children. Even though directionality of these relationships cannot be established, these results emphasize the necessity for an early establishment of an active lifestyle, including sports participation, to allow for the development of various components associated with physical fitness as this may facilitate long-term engagement in sports and physical activity. Considering the low levels of physical education in school with the continued risk of further reduction, the promotion and facilitation of engagement in organized sports would be an important aspect concerning public health. In Germany, roughly 70% of boys and 65% of girls engage in organized sports [29], which could significantly contribute to children's overall physical activity levels as long as sufficient activity time and engagement are assured. In addition, participation in organized sports has been positively associated with the development of psychosocial components such as increased self-esteem, better stress tolerance, and reduced social isolation [61]. These benefits along with the association between sports participation and body weight underline the importance of organized sports in a child's development. Therefore, the facilitation of access to various sports that allow children with different abilities to engage in a variety of activities is a crucial aspect in today's efforts concerning public health.

Authors' Contribution

C. Drenowatz and R. P. Steiner contributed equally to the paper.

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Research Article

"Obese Equals Lazy?" Analysis of the Association between Weight Status and Physical Activity in Children

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Introduction. Literature provides evidence that overweight children are more sedentary. To verify this generalized statement behavior patterns of overweight and nonoverweight children needs to be understood. Therefore, we investigated the distribution of sedentary and activity levels in a quantitative and qualitative way. *Methods*. Data was collected from 37 randomly selected nonoverweight and 55 overweight children. They were 8 to 11 years of age. Height and weight were measured and weight status was characterized by BMI (BMI-percentile, BMI-SDS). Daily PA (physical activity) was measured by direct accelerometry. Spare time and screen time entertainment were obtained by questionnaires. *Results*. The amount of time spent "passive" was significantly higher in overweight children, while nonoverweight children were more "active." The multiple regression model shows a significant association between weight status (BMI-SDS) and activity parameters. Additionally, screen time entertainment was significantly related to BMI-SDS. *Conclusion*. The results support the statement that overweight children are less active than nonoverweight children. The high amount of PA seems to be an important factor to prevent overweight in children given that PA shows the highest correlation to weight status. Quantitative and qualitative measurements are needed for further analysis.

1. Introduction

The increasing prevalence of childhood obesity is currently one of the central public health challenges in modern societies [1, 2]. Studies have shown that overweight children and adolescents generally grow up to be overweight adults [3–5]. Therefore, obesity in childhood is an important risk-factor for obesity and subsequent chronic diseases in later life [6, 7]. In contrast an active lifestyle in childhood should lead to health benefits in adulthood and is influenced by factors that were acquired as habits in early life [8]. Several tracking studies have proven the preventive and positive effects of active behavior in childhood on later life [6, 9–11]. Furthermore, these studies revealed that sedentary behavior during childhood generally leads to a more passive lifestyle in adulthood [8, 12]. Children's sedentary time is associated with more time spent consuming media, such as watching television (TV), computer (PC) use, and playing computer games. Watching TV is the most common sedentary behavior and involves a low fitness level and negative health outcomes [11, 13–15]. Sedentary periods of more than 9 h/per day are also declared as a chronic disease risk factor, independently of the activity time [16].

Besides the focus on PA behavior, interdisciplinary trails for overweight and obese children should support them additionally in their nutritional and psychological behavior because sedentary behavior has a high effect on the energy expenditure and other metabolic processes. Exercise-orientated programs should offer these children possibilities to replace screen time entertainment by daily outdoor and sports activities. Besides interventions programs, sports associations should implement nonperformance oriented workouts simplified for overweight children.

To create such fitted interventions and sports programs it is important to work out reasons why children become overweight and therefore activity and inactivity levels of

overweight and obese children must be identified and analyzed. To assess the complexity of all activity levels and the differences between nonoverweight and overweight children, accurate measurement of sedentary behavior and PA is needed. Accelerometer measurement connected with direct observation continues to be the choice for measuring activity and inactivity in young children [17]. Objective methods like accelerometry lead to accurate measurements of the volume, frequency, intensity, and duration of activity but have no opportunity to obtain a qualitative view on active or sedentary behavior. For qualitative analysis self-report instruments as questionnaires are at present the only available method to assess PA or sedentary behavior [18]. The combination of both methods could lead to a more precise identification of the background and levels of activity and sedentary behavior.

Thus, the aim of this study was to compare the objectively measured results of overweight and nonoverweight children in their habitual and normal daily active and inactive behavior in order to investigate the statement that overweight children are more sedentary and inactive than nonoverweight children. Additionally, we want to obtain a deeper understanding of the background of PA and causes of sedentary behavior by analyzing accelerometry and questionnaire data in a qualitative and quantitative way.

Table 1: Observation of accelerometer rates during direct observation.

Level of acceleration	Kind of sports	Degree of acceleration (acceleration rate)
>60 high activity	Skipping rope	103.4
	Running/jogging	92.3
	Walking/Nordic walking	89.7
	Climbing stairs	72.2
	Basketball	71.5
	Soccer	68.2
	Playing tag	66.6
35–60 moderate activity	Hockey	59.2
	Class breaks	51
	Walk/ride to school	49.1
	Playing	49
	Inline skating	48
10–35 low activity	Playing inside	31
<10 rest	Reading/screen time	5.1
	Sitting	4.1

Values shown are expressed as median degree of acceleration. Data were taken from $n = 20$ children.

2. Methods

2.1. Study Design. Data was collected from 37 randomly selected nonoverweight children from an elementary school and 55 overweight children who were participants in FITOC (FITOC—Freiburg Intervention Trial for Obese children) and visit elementary school as well. These children were measured at the beginning of the intervention trial. All children live in the same city in the south of Germany and were 8 to 11 years of age.

FITOC is a one-year interdisciplinary intervention program for obese children focused on PA enhancement. Participants receive medical examinations, nutritional and behavioral support and attend three physical education classes a week [19].

2.2. Measurements. The height and weight of the study subjects were measured. Weight status was characterized by BMI.

Children were classified as nonoverweight (<90. percentile) and overweight (>90. percentile) according to national reference BMI-percentiles from German children by Kromeyer-Hauschild [20]. The individual BMI data was converted to SD scores (BMI-SDS), using the national reference data of German children [20] to compare the weight groups. The children's parents completed a questionnaire that sought information about the relative time their child spent in various spare time activities and spent in screen-time entertainment such as watching TV, using the computer, or playing videogames.

PA was assessed using an accelerometry-based motion sensor (AiperMotion 440, Aipermon GmbH, Germany). The system uses 3 D acceleration sensors and analyzes data with a disclosed online algorithm. Two different algorithms were used. The first classified the accelerometric data to times with ("active time") and without PA ("passive time") with a 4 s resolution. The second algorithm calculated the "active" acceleration rates into four activity levels (rest, low, moderate, and high) which were based on a pilot study. In the pilot study we observed the children while performing different activities. We evaluated the different activities by direct observation measuring exact acceleration rates after every activity to precisely define the intensity classes. The 4 classes were divided into different degrees of acceleration (acceleration rates). Table 1 shows the results of the pilot study.

Activity distribution was calculated for each child in the assessed time periods. "Non-wear-time" was determined as ≥20 minutes of consecutive nonacceleration and was excluded. For weekdays and weekend days the arithmetic mean of the relative activity was calculated. These results were displayed as minutes in the different activity level.

Subjects were requested to wear the accelerometer on a belt at the hip for 3 weekdays (WD) and 2 weekend (WE) days. The accelerometer recorded the activity from the moment it was turned on; only while sleeping, bathing or dressing the subject removed the device. Data was collected during spring time between 7 am and 9 pm.

2.3. Statistical Analysis. The statistical analyses were performed using SPSS 19.01. All accelerometer data were exported to MATLAB for further analysis. Descriptive statistics were made according to anthropometrical data and physical activity time.

Independent sample t-test exploring differences in physical activity times and levels between overweight and nonoverweight children were performed. Weight class and sex differences between TV time, PC use, and playing games as well

Table 2: Characteristics of the study population.

(a)

$N = 92$	"Nonoverweight" $n = 37$	"Overweight" $n = 55$	P values
Anthropometry			
Age (y)	8.77 ± 0.92	9.28 ± 1.2	$P = 0.04$
Height-SDS	0.47 ± 0.95	0.99 ± 1.16	$P = 0.26$
Weight-SDS	0.13 ± 0.56	2.06 ± 0.61	$P \leq 0.001$
BMI-SDS	−0.13 ± 0.57	2.08 ± 0.56	$P \leq 0.001$
BMI	16.2 ± 1.2	24.6 ± 2.91	$P \leq 0.001$
Sex (boys/girls)	♂37.84%, ♀62.16%	♂36.36 %, ♀63.64 %	

Age in years, height-SDS, weight-SDS, Body-Mass-Index-Standard Deviation Score and BMI expressed as mean ± standard deviation. Sex (boys and girls) was expressed in percentage.

(b)

$N = 92$	"Nonoverweight" $n = 37$		"Overweight" $n = 55$	
Activity[a] (min)	WD	WE	WD	WE
Passive time	329.5 (300; 395)**	349.7 (299; 399)	400.5 (362; 441)	390.7 (307; 468)
Active time	510.5 (445; 540)**	490.3 (441; 540)	439.5 (399; 478)	449.2 (372; 533)
Activity levels (min)				
"rest"	327 (274; 383)**	341.0 (287; 401)*	417.2 (265; 468)	390.0 (298; 457)
"low"	270.5 (236; 300)*	252.2 (202; 284)	244.6 (210; 275)	243.7 (214; 284)
"moderate"	155.5 (134; 193)**	168.5 (134; 196)	129.3 (99; 150)	144.2 (105; 194)
"high"	67.3 (42; 102)*	69.3 (42; 99)*	44.2 (26; 76)	51.0 (28; 81)
Screen-Time hours[b]	WD	WE	WD	WE
TV (>60 min/day)	38.24%*	58.82%*	80%	85.29%
PC (>60 min/day)	2.94%**	2.94%**	37.14%	40%
Games (>60 min/day)	0%**	2.94%**	23.53%	44.12%
Spare-Time activity[c]				
Homework (>60 min/day)	11.76%*		35.48%	
Sports club member	70.59%		57.58%	
Sports club (>3 days/wk)	28.0%*		0%	
Outdoor sports (>6 days/wk)	47.06%*		28.13%	

[a]WD: weekday, WE: weekend. Daily activity time in minutes expressed as median (25th percentile; 75th percentile). Differences were significant (U-Test) between weight classes (**$P < 0.001$, *$P < 0.05$).

[b]Screen-time entertainment (more than 60 min/day) in percent (%) for television (TV), computer (PC), and computer games (Games). Differences were significant (Chi-square test) between weight classes (**$P < 0.001$, *$P < 0.05$).

[c]Spare time activity. Homework more than 60 min/day, Sports club membership, more than 3 sports club sessions per week. Outdoor: "how often does your child play outside per week?" (more than 6 times/week). Differences were significant (Chi-square test) between weight classes (**$P < 0.001$, *$P < 0.05$).

as spare time items were tested by using a chi-square test for categorical variables.

A multiple regression model was used to investigate the correlation between BMI-SDS and physical activity levels as well as spare time variables.

The significance level was set at $\alpha = 0.05$. The study was approved by the Ethics Committee of the University of Freiburg.

3. Results

3.1. Anthropometry. Anthropometric data such as age, weight, height, and BMI-SDS of nonoverweight and overweight children were obtained. Nonoverweight children show in average a BMI-SDS value of −0.13 ± 0.57 (SD) while overweight children of 2.08 ± 0.56 (SD). Results are shown in Table 2(a). All children were in a prepuberal state according to Tanner stages [21, 22]. We did not find gender differences in both weight classes.

3.2. Physical Activity

3.2.1. Active and Passive Times. Regarding the activity behavior of nonoverweight and overweight children, nonoverweight children are significantly more active and less passive than overweight children (Table 2(b)). Comparing active

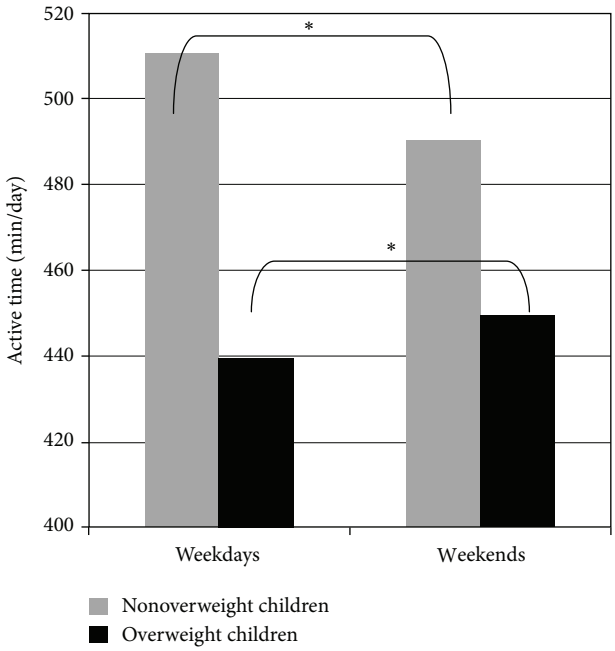

Figure 1: Total active time (min/day) of weight classes during weekdays and weekends. Median values were significant ($^*P$ < 001) within nonoverweight and within overweight children between weekdays and weekends.

and passive times during WD and WE, significant differences were found ($P < 0.001$ and $P = 0.023$), respectively.

Comparing the activity time in the weight groups, nonoverweight children are significantly less active during WE than during WD while overweight children are significantly more active during WE than during WD ($P < 0.001$) (Figure 1).

3.2.2. Activity Levels. During WD nonoverweight children are highly significantly more active and less passive in all activity levels as overweight children: rest ($P \leq 0.001$), low ($P = 0.002$), moderate ($P \leq 0.001$), and high ($P = 0.004$). Only during WE there were no differences found in the categories "rest" ($P = 0.08$), "low" ($P = 0.786$) and "moderate" ($P = 0.135$) while in the category "high", significant differences were found ($P = 0.003$) (Table 2(b)).

3.2.3. Screen-Time Entertainment. Nonoverweight children consume highly significantly lower screen-media than overweight children during WD ($P = 0.001$) and during WE ($P = 0.002$). Overweight children use the computer significantly more often and play more computer games than their nonoverweight counterparts ($P \leq 0.001$) (Table 2(b)).

3.3. Spare Time Activity. Analyzing the questionnaire, nonoverweight children play more frequently outside in their spare time than their overweight counterparts ($P = 0.003$). 47.06% of the nonoverweight children played for more than 6 days/week outside, while only 28.13% of the overweight children did. Furthermore, 13.4% of the nonoverweight children are reported to participate in various organized individual or team sports or other organized physical training session. This was generally through a local or neighborhood association or group more than 3 days/week, while none of overweight children's parents reported any such participation ($P = 0.003$). However, comparing these two weight groups, we found having a membership in such association or groups did not show differences with being in either weight group ($P = 0.513$). Furthermore, no difference between groups was found between the frequency of engaging in individual sports or being active during the weekend ($P = 0.769$).

Nonoverweight children spend significantly less time doing their homework ($P = 0.04$). Overweight children (35.48%) needed more than 60 minutes to complete their homework assignments, while only 11.76% of the normal weight children did (Table 2(b)).

3.4. Regression Models. The multiple regression model shows a significant association between weight status (BMI-SDS) and activity parameters as well as spare time behaviors. A variance of 71.2% was explained through the regression model ($R^2 = 0.71$). The highest influence was given by PA parameters. TV and PC consumption had also a significant influence on BMI-SDS. Table 3 shows the results.

For all activity and leisure time parameters there were no gender differences.

4. Discussion

4.1. Tracking Effect and Sedentary Time. This study clearly demonstrated the association between overweight and sedentary lifestyles. It has been proven that obesity leads to greater negative health consequences in adulthood if children maintain an inactive lifestyle during childhood and adolescence [6, 23]. Passive behavior has been established as a field of research. Therefore, many papers discuss potential negative health outcomes starting their sedentary lifestyle in childhood [7, 16, 24].

For a further discussion of the present study we want to distinguish between sedentary time explained through a higher screen-time entertainment associated with passive time and active time explained through PA, sports club memberships or simply playing outside. While being overweight is widely discussed to have a higher correlation to sedentary rather than to active behavior, sedentary behavior must be considered as independent factor when assessing correlations to overweight [24].

4.2. Passive Time. In this study, "passive time" as well as the lowest activity level ("rest") was associated with sedentary behavior. Furthermore, screen-time entertainment, such as watching TV, using the PC, playing video games, and doing homework was categorized as sedentary behavior. Based on all assessed sedentary time behaviors, overweight children spend significantly more time being passive than their normal weight counterparts. In general, measuring sedentary behavior presents a challenge because there are a variety

Table 3: Spare time variables and accelerometer data associated with BMI-SDS.

Variables	$\beta_{adjusted}$	P value
PA "WE moderate activity"	−0.955	0.001
PA "WE active time"	0.849	0.003
PA "WD high activity"	−0.639	0.000
PA "WD low activity"	−0.574	0.002
PA "WD moderate activity"	0.414	0.016
PC (WD)	0.361	0.021
PC (WE)	0.355	0.035
Age	−0.261	0.042
TV (WE)	0.256	0.017

Linear multiple regression model ($R^2 = 0.71$).
Excluded variables: games (weekday), homework (time/day), sports club frequency, spare time times/week, WE low activity, WE passive time, frequency sport WE, TV (WD), games (WE), WE high activity, WD active time, sports club member, leisure time activity.
PA: physical activity, WD: weekday, WE: weekend, TV: television, PC: computer, BMI-SDS: Body-Mass-Index Standard Deviation Score.

of activities that are defined as "passive time", such as TV viewing, using other screen-time entertainment, or sitting in class. Every following discussed literature uses one of the mentioned "descriptions" to define their sedentary time.

Our finding that being overweight is correlated with passive time is consistent with several studies on children [7, 16, 25–27]. Purslow et al. assessed sedentary behavior in children by accelerometry and used the lowest activity level as "sedentary". This study found a significant association between children's fat mass index and inactivity and confirms our result that overweight children are more passive [28]. TV consumption is the most prevalent sedentary behavior for overweight children and adolescents and involves a low fitness level and negative health outcomes [8, 11, 13, 14]. Janz et al. found a strong association between TV viewing and fatness while assessing body composition in children [12] and proved the association between sedentary behavior and overweight. Only a minority of studies reported less or no difference between weight groups in their sedentary behavior such as a study from Belgium [29]. These studies did not find differences in the amount of inactive play, in the assessed light intensity or sedentary intensity measured by accelerometry, and in children's screen-time behavior during the week [30].

Furthermore, we assessed the time children spent doing their homework and a novel finding in the current study was that we found a significant difference between weight groups. Overweight children spend more time on average doing their homework than nonoverweight children. A possible explanation could be that sedentary lifestyle also influences neurocognitive function and academic performance showing children with low physical activity levels to have poorer academic achievement scores and inferior cognitive performance compared to physically fit children [31–33].

Nearly all studies mentioned indicate that sedentary behavior, independent of levels of active behavior, show negative health outcomes during childhood. Since sedentary behavior is omnipresent, Canadian Sedentary Guidelines were created in 2011 for the enhancement of children's health [34]. This is one first step to reduce sedentary behavior and to promote an active lifestyle to decrease the prevalence of childhood obesity.

4.3. Active Time. Evaluating the active time, our data demonstrates a significant difference between weight classes. In this study active behavior is characterized by accelerometer-based PA levels, playing outdoors, and spending time in sports associations. Nonoverweight children are significantly more active in all activity levels than overweight children.

Correlations between sedentary time and weight status have been discussed above, while we presently focus on studies integrating activity in different levels and overweight.

Screening literature, Deforche et al. reported that nonoverweight children spend more time on average in moderate-to-vigorous physical activity (MVPA) than overweight children [30]. Colley et al. confirm that overweight boys accumulate less MVPA than their nonoverweight counterparts, but this difference was not found in girls [35]. Studies from the United States and Australia found significant inverse linear relationships between PA and both BMI and body fat [36, 37]. One large study from Europe examined the association between PA measured by Actigraph and body composition. Although they did find a correlation between MVPA and body fatness in children, this relation was very weak [38]. Ness et al. objectively measured PA by accelerometry and presented a strong inverse relationship between obesity and MVPA. They compared PA with BMI and body composition measured by DXA scanner [39]. In our multiple regression model, BMI-SDS and time being physically active showed the highest association and a strong inverse correlation between activity and obesity as well.

4.4. Activity Levels during Weekend. Treuth et al. focused on girls aged 11 and found out that nonoverweight children spent more time in MVPA than overweight children, but this difference was smaller on weekends than on weekdays. This fact is comparable with our results showing that nonoverweight children are significantly less active during WE than during WD while, interestingly, overweight children are significantly more active during WE than during WD. Further studies examined and confirmed a lower activity time in nonoverweight children on weekends [30, 40, 41]. This could be caused by regular activity in sports associations and clubs during WD. An explanation for a higher PA level in overweight children on WE could be their parents' spending spare time with them, because it is known that overweight children live more often in single parent families who probably work during week but not during WE [42–44]. This significant difference between WD and WE shows the need of activity support by public health, social and sports organizations, especially in overweight children. Financial encouragement for low income families for an easier accessibility in sports organizations should be implemented. Furthermore, a wide range of offers in all kind of sports should be the first step to decrease the high thresholds for overweight children to take part in sports organizations.

4.5. Spare Time. We asked the parents if their children had a membership in sports associations and clubs, and about the frequency their children took part in organized sports during the week. We did not find a difference between weight groups in having a membership. However, we did find a difference in the frequency; children take part in individual or team sporting events or training sessions during the week. None of the overweight children took part in 3 or more lessons during the week. This is confirmed by an Australian study, where the authors show that overweight children were significantly less involved in community organizations [45]. Trembley and Willms found out that PA in organized and unorganized sports is negatively associated with obesity [46].

PA time is also characterized by playing outside. We observed a lower level of outdoor playing in overweight children. Only few studies examined the spare time activity, but Dolonski et al. found a significant correlation between PA (MVPA) and outdoor play [47]. Veitch et al. focused on the neighborhood social environment and children's weight and found an association between BMI and the time spent outdoors [48]. We only found one study that did not show differences in hours of outside play between overweight and nonoverweight children [30].

All these results show the need of creating interventions and programs that are highly stimulative in nature for overweight children, fitted to their interests to enhance PA. Interventions which reduce anxiety associated with PA should be implemented, and it is a basic necessity to involve overweight children in programs like FITOC. Overweight and obese children may benefit from PA-focused trials that are designed to encourage daily PA. Factors such as fun, variety, family participation, and motivational aspects can help overweight children to recover enjoyment in PA. Furthermore increased sessions to improve the development of fundamental movement skills and PA behavior should be implemented throughout school week. Additionally home activities that encourage children to be more active should help to reduce screen-based entertainment. This is a challenge for public health programs, teachers, and sports organizations.

4.6. Limitations. Quantifying and measuring PA in the complex behavior of children is a difficult undertaking. Children's PA is characterized as spontaneous and irregular because they have a short attention span, in contrast to a consistently distributed PA in adults. Several studies used for children's PA assessment were proxy reports, diaries, or direct observation to define PA [49–51]. Proxy reports are decidedly less objective because they were filled out by parents [52]. In our study parents completed a questionnaire that sought information about the time their child spent in spare time activity and screen-time entertainment as well. To prove objectivity we compared activity times measured by accelerometry and answers given by questionnaires. For different levels of PA and sedentary time, accelerometry continues to be the method of choice. Accelerometers have the advantage to evaluate the frequency, intensity, and duration of PA over a longer time-period and are objective [53]. Although accelerometers have their limitations being not used for qualitative analysis, they have currently a great deal of utility, especially in young children [53].

For our study we chose children 8–11 years old, because this age group takes part in the intervention trail FITOC. The nonoverweight children were recruited in this age group too. We did not find gender differences in their activity behavior, in their spare time behavior, or in their media consumption. Therefore different gender distribution in both weight groups does not affect the results and gender differences do not have to be mentioned in this paper.

5. Conclusion

This study highlights strong evidence that overweight children spend more time sedentary and accumulate significantly lower levels of PA than their nonoverweight counterparts. The problem of overweight and obesity leads to negative health outcomes and must be handled immediately with public health strategies. The present worldwide change in children's sedentary lifestyle makes it a fruitful area for further research.

The current finding illustrates the need to establish interventions, especially weekdays, targeted to overweight children, because PA plays an integral role for immediate and long-term health implications. More proposals must be created inside sport associations for overweight children: enjoyable and doable, not performance-oriented and without competition. Furthermore, intervention research must move towards to identify how feasible intervention arrangements can be established in the education and health system to obtain long-term effective impacts.

5.1. What Is Already Known about the Study? There is a link between inactivity and overweight in children.

Overweight children have a significantly higher screen time entertainment (TV, PC) than nonoverweight children.

Nonoverweight children are more active (outdoor play, daily PA) than overweight children.

5.2. What Does This Study Add? In contrast to other studies measuring PA objectively but only quantitatively, or studies exploring PA only by self-report but in a more qualitative way, this study combines PA measured by objective accelerometry and by proxy report of parents who gave additional information about PA time and spare time activity. This leads to a significant quantitative and qualitative analysis of PA and sedentary behavior.

Overweight children are in general more active on weekends and, with respect to the "moderate" activity level, as active as their nonoverweight counterparts. Thus, overweight children are not always as inactive as mentioned.

Overweight children spent more time doing their homework than nonoverweight children. That could be caused by the evidence-based fact that sedentary lifestyle also can influence and reduce neurocognitive function.

Conflict of Interests

The authors are free from any conflict of interests.

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Review Article

Prader-Willi Syndrome: Clinical Aspects

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Prader-Willi Syndrome (PWS) is a complex multisystem genetic disorder that shows great variability, with changing clinical features during a patient's life. The syndrome is due to the loss of expression of several genes encoded on the proximal long arm of chromosome 15 (15q11.2–q13). The complex phenotype is most probably caused by a hypothalamic dysfunction that is responsible for hormonal dysfunctions and for absence of the sense of satiety. For this reason a Prader-Willi (PW) child develops hyperphagia during the initial stage of infancy that can lead to obesity and its complications. During infancy many PW child display a range of behavioural problems that become more noticeable in adolescence and adulthood and interfere mostly with quality of life. Early diagnosis of PWS is important for effective long-term management, and a precocious multidisciplinary approach is fundamental to improve quality of life, prevent complications, and prolong life expectancy.

1. Introduction

PWS (OMIM number 176270) is a complex multisystem genetic disorder originally described in 1956 by three Swiss doctors, Prader et al. [1]. PWS was the first recognized disorder related to genomic imprinting in humans [2] and is caused by the lack of expression of paternally inherited imprinted genes on chromosome 15q11–q13. In several studied populations prevalence has been estimated to be 1/15,000–1/25,000.

The syndrome shows great variability, with changing clinical features during a patient's life. A newborn might suffer from severe hypotonia with feeding problems and global developmental delay. During infancy these characteristics impede the acquisition of gross motor and language milestones. A PW child develops hyperphagia during the initial stage of infancy that can lead to precocious obesity if left uncontrolled. This is most probably caused by a hypothalamic dysfunction, which impedes the sense of satiety. This hypothalamic dysfunction is also responsible for growth-hormone (GH) and thyroid-stimulating hormone (TSH) deficiencies, central adrenal insufficiency, and hypogonadism. During infancy, the PW child shows a characteristic problematic behavioral pattern, which has been reported to worsen with age. Patients sometimes present psychosis.

Early diagnosis of PWS is important for effective long-term management. In fact, the multidimensional problems of patients with PWS cannot be treated with a single intervention. A precocious multidisciplinary approach is fundamental to improve quality of life, prevent complications, and prolong life expectancy.

PWS can be considered an excellent example of how early diagnosis and meticulous management can markedly improve long-term outcome, despite the genetic background.

2. Diagnosis

PWS diagnosis is based on specific clinical features, and it is confirmed by genetic testing.

2.1. Clinical Features. Although diagnostic molecular testing for PWS is currently available, the clinical identification of patients remains a challenge as many features of PWS are nonspecific while others evolve over time or can be subtle [3].

In 1993, Holm et al. [4] proposed consensus clinical diagnostic criteria for PWS. In this consensus, features were divided into three groups: major criteria (1 point), minor criteria (1/2 point), and supportive criteria. Clinical diagnosis requires five points (at least four of them major) at age <3 years; eight points (at least five of them major) at age 3 years or older.

In 2001 Gunay-Aygun et al. [5] proposed a revision of these diagnostic criteria (Table 1) to help identify appropriate patients for DNA testing for PWS. The suggested age groupings are based on characteristic phases of the natural history of PWS. Some features, such as neonatal hypotonia and feeding problems in infancy, help diagnose the syndrome during the first years of life, whereas others, such as excessive eating, are useful during early childhood.

2.2. Genetic Findings. PWS, together with Angelman syndrome (AS), represents perhaps the best example of genomic imprinting in humans. Genomic imprinting is an epigenetic process by which the male and the female germ lines confer specific marks (imprints) onto certain gene regions. Probably <1% of our genes are imprinted with an expression pattern determined by the parent of origin [6–8].

The PWS region is found in a 5-6 Mb genomic region on the proximal long arm of chromosome 15 (15q11.2–q13; Figure 1). The complex phenotype is due to the loss of expression of several paternally genes on chromosome 15q11.2–q13 [9, 10].

Three main molecular mechanisms result in PWS.

(1) *Paternal microdeletion* is responsible for 75–80% of cases.

(2) *Maternal uniparental disomy (UPD)* is responsible for 20–25% of cases.

(3) *Imprinting defect (ID)* is responsible for 1–3% of cases.

(4) *Other defects* is such as balanced and unbalanced translocations, which, together with ID, are responsible for the majority of familial cases.

2.2.1. Genotype-Phenotype Correlation. Genotype-phenotype correlation is not possible, because no features are known to occur exclusively in individuals with one of the genetic classes. However, some studies identify significant statistical differences between the two largest genetic subtypes (deletion and UPD). For example, postterm delivery is more common in UPD patients. They are less likely to show hypopigmentation [11, 12], the typical characteristic facial appearance [11, 13], or possess jigsaw-puzzle skills [14]. In most studies, patients with UPD have a somewhat higher verbal IQ and milder behavioral problems [15–17]. However, psychosis [18] and autism spectrum disorder [19, 20] occur with significantly greater frequency among those with UPD. Individuals with the slightly larger, type-1 deletions (BP1–BP3) show poorer adaptive behavior, and lower intellectual ability and academic achievement than those with type-2 deletions (BP2-BP3) deletions [21, 22]. Two other studies found fewer clinically significant differences between individuals with these two deletion types [23, 24].

2.2.2. Genetic Counseling. Knowing the specific genetic etiology in individuals with PWS is essential for the appropriate genetic counseling of affected families. The risk of PWS recurrence in families with affected children is usually less than 1%, except for inherited mutation in the imprinting center (up to 50%), and translocation inherited mutation with break point in the 15q11.2–q13 region (up to 25%).

2.2.3. PW-Like Patients. The term "PW-like" is used to indicate a patient with clinical features that are very similar to PW, but without the confirmation of a classical genetic subtype that can cause the syndrome.

The literature reports many PW-like cases, but also many reports of the association between these patients and some particular genetic anomalies or syndromes.

The most frequently reported are the associations between PW-like and

(i) Fragile X syndrome [25, 26],

(ii) Klinefelter syndrome [27, 28],

(iii) interstitial deletion in 6q [29],

(iv) subtelomeric deletion 1p36 [30, 31].

2.3. Genetic Tests. Various types of genetic test can be used for PWS diagnosis and to characterize the different subtypes (Figure 2) [32].

methylation-specific-multiplex ligation-dependent probe amplification analysis (MS-MLPA) combines both DNA methylation analysis and dosing analysis across the PWS region and can be considered the gold standard for PWS diagnosis in 99% of cases. This test shows the absence of the paternal allele using a methylation analysis to measure the amplitude of deletion (type 1 or type 2) and exclude suspect UPD or imprinting defects.

The karyotype is useful in association with MS-MLPA to point out balanced translocation whose breakpoint might be in the critical PWS region (15q11–q13).

Microsatellite analysis is necessary only if MS-MLPA does not show deletions in the critical PWS region, but just paternal allele absence at methylation analysis. It shows UDP (both alleles belonging to the mother) and also specifies if there is a heterodisomy (two mother alleles that are different from each other) or isodisomy (the same maternal allele in a double copy). If this analysis shows a biparental pattern, there is indication of mutation or microdeletions of the imprinting center.

3. Clinical Presentation

PWS is a multigenic pathology that shows great clinical variability that shows great clinical variability. Features change from patient to patient and even during the lifetime of the individual patient.

We have designated 4 age classes that can help the physician to outline ideal lifelong PW patient followup taking

Table 1: Published revised diagnostic criteria for PWS, Gunay-Aygun et al. [5].

Age at assessment	Features sufficient to prompt DNA testing
Birth to 2 years	Hypotonia with poor suck.
2–6 years	(1) Hypotonia with history of poor suck. (2) Global developmental delay.
6–12 years	(1) History of hypotonia with poor suck (hypotonia often persists). (2) Global developmental delay. (3) Excessive eating (hyperphagia; obsession with food) with central obesity if uncontrolled.
13 years through adulthood	(1) Cognitive impairment, usually mild mental retardation. (2) Excessive eating (hyperphagia; obsession with food) with central obesity if uncontrolled. (3) Hypothalamic hypogonadism and/or typical behavior problems (including temper tantrums and obsessive-compulsive features).

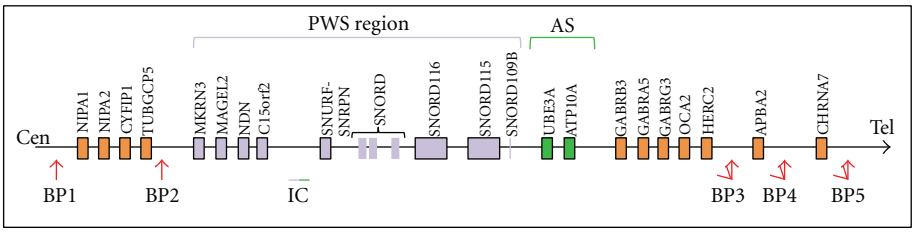

Figure 1: Schematic representation of the region 15q11.2-q13. The Prader-Willi syndrome (PWS) region is shown in violet, and Angelman syndrome (AS) region is shown in green. The red arrows indicate the three deletion breakpoints common to PWS and AS (BP1, BP2, and BP3). On rare occasions, there will be a distal breakpoint at BP4 or BP5. Type-1 deletions (T1D) extend from BP1 to BP3, and type-2 deletions (T2D) extend from BP2 to BP3.

into consideration all the problems these patients might have to face.

3.1. From Birth to 3 Years. Pregnancy is generally normal, but some mothers may report decreased fetal activity, and newborns are often found in the breech position at time of delivery. Premature delivery may occur, and newborns that are adequate for gestational age frequently have low weight and length at birth.

The majority of newborns with PWS present marked neonatal axial hypotonia (babies are described as "floppy"); this is associated with lethargy, decreased movement, weak crying, and poor reflexes, including poor sucking, often resulting in failure to thrive [33, 34].

The baby can present dysmorphic characteristics, such as narrow bifrontal diameter, dolichocephaly, almond-shaped eyes, downturned angles of the mouth with abundant and thick saliva, and small hands and feet. These are less pronounced at birth but can become more evident with age.

Newborns generally present the clinical signs of hypogonadism. In males, the penis may be small; more characteristic is a hypoplastic scrotum that is small, poorly rugated, and poorly pigmented. Unilateral or bilateral cryptorchidism is present in 80–90% of males [35, 36]. In females, genital hypoplasia is often overlooked; however, the clitoris and labia, especially the labia minora, are generally small from birth.

Hypotonia and hypogonadism are the first manifestations of a primitive hypothalamic alteration, which many studies indicate to be at the base of PWS. This central deficiency leads to many manifestations, in particular a pituitary hormonal deficit (GH, TSH, central adrenal insufficiency [37]), satiety alteration, sleep disturbances, and a tendency for dysthermoregulation.

Although hypotonia slowly evolves over time, gross motor and language milestones are delayed. Early milestones are reached on average at double the normal age (e.g., sitting at 12 months, walking at 24 months, and saying words at 2 years)[38].

3.2. From 3 to 10 Years. During preschool age, PW patients develop a food obsession; children become overweight as a consequence of an insatiable appetite and compulsive eating, which can lead to morbid obesity in adolescence and adulthood if not kept under control.

PWS eating habits are complex and multifactorial. They are thought to be associated with abnormalities in the hypothalamic circuitry or the peripheral satiety signals [39, 40].

PWS individuals show differences in various gut hormones, including high levels of obestatin (an anorexigenic hormone) in infancy, with markedly elevated levels of ghrelin (an orexigenic hormone) in childhood and adulthood. The structural brain abnormalities present in these individuals might also contribute to appetite aberrations [41]. Functional MRI studies indicate that these individuals assign a high reward value to food with increased activation of the limbic and paralimbic areas of the brain that drive eating

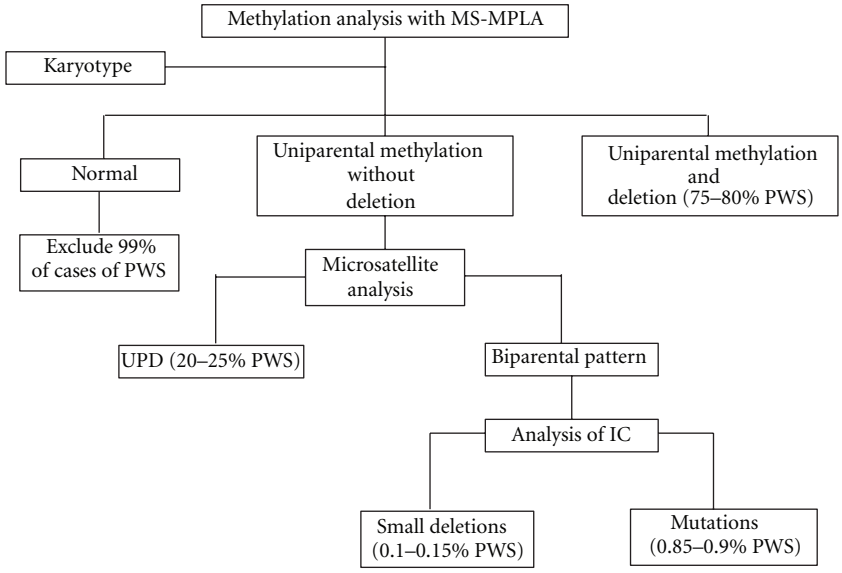

Figure 2: Algorithm for genetic testing for PWS. MS-MPLA: methylation-specific-multiplex ligation-dependent probe amplification analysis. UPD: uniparental disomy. IC: imprinting centre.

behavior, even after meal, showing that the brain influencing appetite in this syndrome.

In 2011, McAllister et al. [42] reviewed eating behavior in PWS. They concluded that a genetic abnormality might be the cause of fetal malnourishment or fetal starvation, leading to neonatal failure to thrive and also causing feeding problems. Ghrelin may be involved in the instigation of the binging and hyperphagic stage, and later development of atypical reward circuitry in response to food might be the result of altered pathways generated in the early binging stages in childhood, combined with insensitivity to satiation cues, such as leptin levels. Examining reward pathways by neural imaging in response to food in younger children, for example, may elucidate the development of the hyperresponsive circuitry [42].

Growth restriction is a frequently observed sequel of PWS; approximately 90% of affected individuals are short in stature, probably resulting from GH deficiency [37].

During the first 6 years of life, children with PWS often do not achieve normal levels of cognitive, motor, and language development. Indeed, according to one study, these individuals have a below-average IQ of about 70 [43–45]. A review of cognitive ability among 575 affected individuals confirms this, showing that just 5% of patients had a normal IQ (i.e., >85). Borderline mental retardation was observed in 28% of patients, while 34%, 27%, and 5%, respectively, were mildly, moderately, or severely mentally retarded [45].

During this period, many PW sufferers display a range of behavioral problems that include both excessive appetite and lack of food selectivity. There is also a high incidence of stubbornness, verbal perseverance, skin picking, and temper tantrums.

Despite hypogonadism generally causing incomplete, delayed, and sometimes disordered pubertal development, in approximately 15–20% of patients of both sexes, premature adrenarche or precocious puberty often occurs [35, 46].

3.3. From 10 to 18 Years. During adolescence, behavioral problems and hyperphagia become more noticeable.

In experimental settings, PWS individuals have been seen to consume around three-to-six times more than the normal caloric intake at a given meal [47, 48]. Overeating can lead to stomach rupture [49], and PWS individuals have also been known to steal and hoard food. These individuals have also been reported to eat inappropriate food, such as uncooked chicken, or even to eat nonfood items.

Central obesity results from the combination of uncontrolled food intake, a low metabolic rate, and a decreased activity level (resulting in a decreased total caloric requirement). Obesity-related complications appear, such as cardiorespiratory insufficiency, obstructive sleep apnea, thrombophlebitis, and chronic leg edema, and are the major causes of morbidity and mortality [50].

The severity of behavioral problems increases with age and body mass index and can then diminish in older adults. Psychosis is evident by young adulthood in at least 5–10% of individuals [51–53]. Behavioral and psychiatric problems interfere mostly with quality of life in adolescence and adulthood.

Hypogonadism causes incomplete, delayed, and sometimes disordered pubertal development. Primary amenorrhea or oligomenorrhea are present in females. Infertility is the rule in both sexes although a few instances of reproduction in females have been reported and presented [54, 55]. Although hypogonadism in PWS has long been believed to be entirely hypothalamic, resulting in low gonadotropins and subsequent low gonadal hormones, recent studies have suggested a combination of hypothalamic and primary gonadal deficiencies [56–58].

3.4. The Adult. The quality of life of adults with PWS is largely conditioned by the degree of obesity, the presence of its complications, and behavioral problems.

4. Management

Patient management has to be tailored, due to the clinical variability between patients, but also to variability in the same patient throughout this or her lifetime. Therapeutic decisions and clinical followup need to consider each problem that a patient might have to face. A multidisciplinary team, consisting of neonatologists, pediatricians, endocrinologists, orthopedic surgeons, psychologists, psychiatrists, physiotherapists and urologists, has to deal with all of the patient's medical and psychological problems.

4.1. Nutrition. The maintenance of adequate and appropriate nutrition is fundamental to the treatment of people with PWS at every age.

A correct approach should consider the two distinct nutritional stages of every PW patient:

(i) stage 1: poor feeding and hypotonia, which can often cause a failure to thrive;

(ii) stage 2: "hyperphagia leading to obesity" [5, 40, 59].

4.1.1. Feeding Support. During the first two months of life, most PWS infants are unable to suck an adequate quantity of milk from the breast or the feeding bottle, and they have to be fed by gavage. The use of a gastrostomy tube (generally using a button-style device) can be avoided in most cases, but if, after considering the risks and benefits of both approaches, a decision to use a gastrostomy tube is made, the device should be promptly removed when no longer needed.

Milk requirement is that of other infants of the same age and weight. Children should not be given simple sugars for a "sweet taste."

Infants may require feeding support for several months. Caloric needs may sometimes be somewhat reduced in infants with PWS, who typically do not spontaneously demand feeding. The infant's diet must therefore be adjusted to maintain appropriate weight gain as determined by frequent weight checks. Increased caloric density can be helpful.

4.1.2. Dietary Control. Incorrect eating is one of the most serious disorders affecting the lives of children and adults with PWS. Hyperphagia is a serious chronic problem for children with PWS, together with their families, and it can severely limit independence in adult life due to the risk of life-threatening obesity.

Controlling food-related behavior is complex, aiming to limit the child's access to food, reduce exposure that can cause the child to think about food, and promote a daily routine that helps obtain good weight control. Relatives and friends also have to understand that "sneaking" food to the child with PWS is not a demonstration of affection as, on the contrary, it undermines the child's nutritional regimen and sense of wellbeing.

When hyperphagia occurs the caloric intake needs to be reduced. The diet should have a balanced distribution and be rich in fiber, and the caloric intake should be about 75–80% that of a healthy child of the same age.

During adulthood, the caloric intake should be below 1000–1200 kcal/day to maintain stable weight structure, or between 800 and 1000 kcal/day to lose weight. Dietary restriction should anyway be balanced, and complex carbohydrates should be preferred.

Pharmacological treatment, including available anorexigenic agents, has not been of benefit in treating hyperphagia although there are some published placebocontrolled studies [40, 60]. The potential benefits of newer agents, such as endocannabinoid antagonists, are still under examination in PWS. Recent concerns regarding psychiatric side effects need careful monitoring in these patients.

Restrictive bariatric surgery, such as gastric banding or bypass, has not been seen to reduce hyperphagia or achieve long-term weight reduction and are associated with unacceptable morbidity and mortality [61, 62]. Whereas some of the reports using biliopancreatic diversion reported successful weight loss, there have been frequent complications from the resulting intestinal malabsorption. Bariatric surgery should only be considered when the patient's excessive weight becomes life threatening. Strict diet control and postsurgical followup are mandatory.

4.2. Motor Program. The motor program has to consider the various necessities during a patient's life; in newborns the goal is to improve axial hypotonia, while in childhood and adulthood the patient's physical, socials and metabolic condition needs to be focused.

4.2.1. Physiotherapy. The newborn is characterized by a variable grade of hypotonia that influences many aspects of normal development (delayed gross motor milestones) and growth (feeding difficulties).

Even when hypotonia evolves slowly, we suggest the prompt introduction of personal training programs. These programs must be supervised by physiotherapists and maintained by parents. They help counteract the hypotonic PWS infant's difficulties in overcoming gravity during early life. This is a particularly sensitive period for motor development and skills acquisition and might have consequences regarding cognitive and social development.

4.2.2. Physical Activity. Physical activity and sports are a fundamental therapy for PWS patients.

During childhood, physical activity

(i) improves physical functions,

(ii) promotes socialization,

(iii) helps improve caloric expenditure, together with diet,

(iv) is one of the best ways to limit access to food.

We suggest regular daily physical activity of around 30 minutes. Any kind of sport is possible, and parents should consider the abilities and tastes of their children when choosing.

Although hypotonia improves with age, it persists into adulthood, together with reduced muscle mass. Regular exercise is therefore an important part of everyday life.

In a recent study, Vismara et al. provided an effective and simple home-based training program representing a continuum of the rehabilitation process outside the hospital, which is a crucial issue in chronic conditions. In fact, following six months of daily activity patients were seen to improve their physical function [63].

4.3. Endocrinological Aspects. As already stated, the hypothalamic dysfunction at the base of PWS contributes to the development of multiple endocrine disorders, such as adrenal insufficiency, GH deficiency, LH/FS disorder, and thyroid dysfunction.

4.3.1. Adrenal Insufficiency. Several reports show a mortality rate in PWS estimated at 3% yearly [64, 65]. Disturbances in the hypothalamus-hypophysis-adrenal (HHA) axis are thought to be responsible for these events or, at least, to represent concurrent factors consistent with an inadequate or late response during infection or relevant dehydration episodes. This hypothesis is supported by pathological findings. Adrenal atrophy has been documented autoptically in a number of such cases [66], and small volumes of the hypothalamic paraventricular nuclei with decreased cell number were demonstrated in PWS adults [67]. Although these aspects have been described in PWS, the genetic basis of putative central adrenal insufficiency (CAI) is far from being unraveled, as the molecular mechanisms leading to PWS phenotype are still largely unknown.

From a functional viewpoint, some studies reveal a differing prevalence for this problem. De Lind van Wijngaarden et al. using the metyrapone test found that the hypophyseal response to adrenal inhibition was insufficient in 15 out of 25 (60%) PWS patients [68]. Two recent reports on 41 and 57 PWS patients found no cases of CAI by employing a low-dose (LDTST) and a standard ACTH stimulation test (250 μg), respectively [69, 70]. The Study Group for Genetic Obesity of the Italian Society of Pediatric Endocrinology and Diabetology (SIEDP/ESPED) designed a study that confirms that clinically relevant CAI in pediatric PWS patients is rare (14.3% to LDTST), with one third of them (4.8%) also having suboptimal response to a second test. The authors suggest [71].

According to the literature, the administration of glucocorticoids during episodes of moderate/severe stress is recommended (hydrocortisone at 30–70 mg/m^2/day divided into 3 doses Continuous replacement should be limited to cases with clinical signs of adrenal insufficiency, as for other nonsyndromic forms of CAI.

4.3.2. Growth Hormone (GH) Deficiency. There are many data indicating reduced GH secretion in PWS patients. Low peak GH response to stimulation tests, decreased spontaneous GH secretion, and low serum IGF-I levels have been documented in at least 15 studies involving about 300 affected children [37]. Clinical features of the condition also support the presence of GHD in PWS. Both PWS and GHD are characterized by short stature, obesity with extra fat deposits over the abdomen, abnormal body composition with reduced muscle mass and decreased bone density, and, in some patients, retarded bone age [4, 72]. Patients with PWS are therefore GH deficient although the degree of GH deficiency may vary from mild to severe.

Guidelines for GH therapy in PWS children have been drawn up by the Italian Drug Agency (AIFA) note number 39 and do not depend on the presence of GH deficiency.

In accordance with the literature [50], we suggest beginning GH therapy during the first year of life after performing the following:

(i) polysomnography and ENT evaluation,

(ii) fasting glucose and OGTT (glucose 1, 75 g/Kg, to maximum 75 g),

(iii) blood sample for: IGF1, fT4, TSH,

(iv) spine X-ray,

(v) cardiologic evaluation with echocardiography.

The recommended dosage is 0, 01-0, and 03 mg/Kg/day, adjusted on IGF1 levels, which should not exceed + 2SDS. It is preferable to start with a dose corresponding to 1/3 of the minimal dosage. GH therapy should not be started in the presence of obstructive sleep apnea syndrome (OSAS), adenotonsillar hypertrophy, severe obesity, glucidic intolerance, and/or instable scoliosis. Interruption of therapy should be evaluated if scoliosis, glucose intolerance, or OSAS deteriorate.

When the individual stops growing in height, evaluation of the GH secretory pattern is required through ITT, or rather using the GnRH-arginine test that has greater tolerance. For adolescents in therapy, evaluation of the GH secretory pattern must be preceded by a therapeutic washout of at least 1-2 months. In patients with GH deficit (lower than 3 ug/L) a therapeutic pattern not involving weight is recommended, starting with a standard dose of 0.2 mg/day, which can be modified based on IGF1 levels.

During GH therapy, it is fundamental to carry out periodic monitoring of

(i) polysomnography and ENT evaluation at 6 weeks–3 months–6 months after the start, and whenever necessary,

(ii) fasting glucose and OGTT, IGF1, fT4, TSH: 1 month after the start, and whenever necessary,

(iii) orthopedic evaluation and spine X-ray whenever necessary,

(iv) cardiovascular function evaluation every 6 months, or whenever necessary.

In children with PWS, the aims of GH treatment are to improve growth during childhood, adult height, and body composition. There is much evidence that this therapy has multiple beneficial effects on growth and body composition. In particular, it decreases fat mass and increases muscle mass, and it may have a beneficial effect on weight gain, and possibly appetite, in individuals with PWS [37, 73]. Infants with PWS treated with GH therapy show improved head circumference, height, BMI, body composition (with

improvement of lean muscle mass and delay of fat tissue accumulation), body proportions, acquisition of gross motor skills, language acquisition, and cognitive scores. Several studies have documented the safety and efficacy of GH treatment in adults with PWS on body composition and quality of life [74, 75].

4.3.3. Disorder of Gonadotropins. Hypothalamic dysfunction can cause LHRH-LH/FSH axis disorders. In general, the patient shows hypogonadism from birth, but in some PW children precocious adrenarche or early puberty can occur.

(a) *Hypogonadism*: hypogonadism is a consistent feature in both males and females with PWS, and hypogenitalism is present, even at birth. There is increasing evidence to implicate both central and peripheral origins for hypogonadism, at least in males [76].

At birth, both sexes can have clinical signs of hypogonadism: females show genital hypoplasia (clitoris and labia minora), while males have cryptorchidism, scrotal hypoplasia, and small testicular volume. Cryptorchidism is present in over 80% of boys from birth [35, 36]. At present there is no consensus in the literature as to the best treatment to use. Our experience suggests human chorionic gonadotropins (HCG) therapy from 6 to 12 months with a dosage of 250 U, while from 1 to 5 years a dosage of 500 U should be used twice a week for 6 weeks.

Before and during therapy regular clinical evaluation, testosterone dosage and testicular ultrasound are necessary. When therapy does not have positive results, surgical correction needs to be considered before 2 years of life, or as soon as possible when the child is older. During adolescence patients can show delayed or incomplete pubertal development, and it is therefore necessary to consider hormonal treatment for the induction, promotion, or maintenance of puberty. Before any therapy is carried out, the following need to be considered:

(i) dosage of LH, FSH, estradiol (in females), and testosterone (in males) both basal and after GnRH

(ii) pelvic ultrasound in females,

(iii) testicular ultrasound,

(iv) dual-energy X-ray photon absorptiometry (DEXA),

(v) evaluation of thrombophilic status in females.

For the induction and maintenance of puberty there is no consensus regarding best therapy. We suggest testosterone in males (25 mg once a month, which after 3 months can be increased to 50 mg once a month if well tolerated), and estrogen (incremental dosage up to complete development) and progesterone in females (in general after around 24 months from start of estrogen).

Patients with PWS have low bone mineral density (BMD) and are at risk of osteoporosis related to sex-steroid and GH deficiencies, and low muscular activity with elevated biochemical markers of bone turnover [77–80]. Reduced BMD in PWS is associated with high risk of fracture in the long bones, as well as the small bones, of the hands and feet, with some patients suffering multiple fractures [81]. These findings support the need for hormone therapy, particularly sex-steroid replacement, during adolescence, and maintenance during adulthood. Estrogen, and androgen status should be monitored yearly during adolescence and adulthood and BMD assessed as indicated by DEXA.

Infertility is the rule in both sexes although a few instances of reproduction in females have been reported [54, 55].

(b) *Precocious sdrenarche and early puberty*: Isolated premature pubarche has been reported in 14% and precocious puberty in 4% of males and females [35, 82, 83]. There is no consensus as to the management of either of these conditions. Some investigators have suggested the use of hydrocortisone in premature pubarche to decrease adrenal androgens when associated advancement of bone age is present; treatment with GnRH analogs must be reserved for selected patients [35].

In some patients with advanced bone age and hyperandrogenism we propose cyproterone acetate therapy. In these patients we generally obtain a slowdown of both bone age and androgen values. This drug is off-label, and parental consent is therefore necessary.

4.3.4. Thyroid Dysfunction. In PWS children both central and peripheral hypothyroidisms have been documented. These can be congenital or of late onset [84, 85].

Blood levels of fT4 and TSH should be kept under control: those levels must be monitored at birth, and thereafter yearly (or every 6 months during GH therapy).

In the presence of primary or secondary hypothyroidism L-thyroxine therapy is required.

We recommend a dose of 5-6 mcg/Kg/day (8 mcg/Kg/day in infants <1 year old), which can be modified following levels of fT4 and TSH in primary hypothyroidism, or just fT4 (that should be maintained in the upper zone of the normal range) in secondary hypothyroidism.

4.4. Psychological/Psychiatric Support. A characteristic behavioral profile with temper tantrums, stubbornness, controlling and manipulative behavior, compulsivity, and difficulty with change in routine becomes evident in early childhood in 70–90% of individuals with PWS. Behavioral and psychiatric problems most interfere with the quality of life in adolescence and adulthood.

Interventions concerning behavioral problems must be coordinated by specialists (psychologists, psychiatrists, and doctors), primary care providers, parents, and other family members.

Psychological support during infancy is fundamental for parents and children alike. Early logopedic therapy should be carried out to prevent language disorders. Due to their low cognitive level, PW children should receive learning support during school time.

In adolescence and adulthood some patients develop psychosis that requires pharmacological treatment [53, 86, 87]. In our experience, it is advisable to start treatment with psychotropic drugs at low doses, due to the possible hyperresponsiveness or paradoxical effects induced by commonly

used. The drugs used are benzodiazepines, classical antipsychotics and atypical antipsychotics, mood stabilizers, and selective serotonin reuptake inhibitors. Molecules lacking orexigenic action, or with a lower capacity to induce increased appetite, such as risperidone and fluoxetine, are preferable. Topiramate might help combat the skin-picking phenomenon [60].

4.4.1. Casa Sora. The nonprofit (ONLUS) foundation "Casa Sora Per Voi" [88] is the first Italian project to offer PW children, adolescents, adults, and their families the possibility of formative stays. This project stems from the need of a controlled environment, where patients can learn to cope with their daily lives, socialize, and experience nature and animals.

Various specialists are involved, such as dieticians and psychologists, who plan numerous activities. Families, individuals, and healthcare professionals meet during structured daily programs for adults and children; the children are involved in programmed psychological activities, while their parents and affiliated professionals attend lectures and group discussions.

The house is in an isolated hilly location near lake Iseo and is completely surrounded by greenery and uncontaminated nature. Daily activities include outdoor physical exercise, group experiences in contact with nature in a serene and stimulating environment, and psychospecific recreational and artistic tasks.

4.5. Other Problematics

4.5.1. Orthopedic Problems. Scoliosis is a frequent feature observed in children with PWS (30%–70%) and may be explained partly by hypotonia and obesity [81, 89–91]. Regular clinical assessment is required at each visit, and periodic spinal X-rays are useful, whether or not the patient is receiving GH. Surgical treatment is indicated in severe early-onset scoliosis-kyphosis, and in adolescents near skeletal maturity. Due to the possibility of complications, surgical treatment requires a multidisciplinary team with expertise in the management of scoliosis and PWS.

4.5.2. Ophthalmological Problems. Early screening and correction for myopia, hypermetropia, or other eye problems are recommended. Strabismus is also frequent and may require surgery.

4.5.3. Orthodontic Problems. Abnormal enamel and frequent caries have been previously reported, but in a recent survey PWS patients presented with a more favorable oral health status than those in previous studies [92]. This status is worsened by poor salivary production, which requires education for both parents and children. Education for regular daily drinking and products designed to increase saliva flow might help prevent dental complications. Orthodontic treatment is often needed.

4.6. Medical Alerts

4.6.1. Anesthesiological Risk. PWS patients have a higher anesthesiological risk characterized by an exaggerated response to hypnotic drugs, ventilation difficulties due to dysmorphic facial conformation, hypoxia, breathing problems, and thermoregulation control. These phenomena are more frequent and severe in obese patients that can have obstructive apnea and right ventricular hypertrophy and failure due to pulmonary hypertension. These conditions require preventive cardiology and pulmonary evaluation. Moreover, following surgery patients should be sent to an intensive care unit, and some characteristics must be considered:

(i) high pain thresholds,

(ii) thermoregulation disorders. Although there is no indication for a predisposition to malignant hyperthermia in PWS, the use of depolarizing neuromuscular-blocking drugs (e.g., succinylcholine) should be avoided unless absolutely necessary,

(iii) dense salivation could compromise airway patency, especially during extubation,

(iv) hypotonia reduces cough reflex efficiency in clearing airways.

4.6.2. Acute Gastric Distension. In the literature there are at least 8 cases of acute gastric distension, and at least 3 cases of death following gastric rupture in PWS patients. The basis of this serious and potentially mortal complication is the presence of hyperphagia, a high pain threshold, the inability to vomit, and delayed gastric emptying. It is very important to keep PWS patients under strict regular control in the presence of large quantities of available food (banquets, parties, supermarkets, etc.). Furthermore, in the presence of abdominal pain and/or vomiting, an abdominal X-ray has to be carried out to exclude gastric perforation.

5. Follow Up

The PW patients need a lot of specialistics controls:

(i) axiological evaluation: length/height, weight, head circumference, BMI (Figure 3),

(ii) nutritionist/dietician evaluation,

(iii) blood sample: oral glucose tolerance test (OGTT), HbA1c, total cholesterol and HDL, triglyceride level, uricemia, thyroid function (TSH, fT4), IGF1,

(iv) evaluation of pubertal development: dosage of LH, FSH, estradiol (in females) and testosterone (in males) both basal and after GnRH,

(v) bone age (left hand X-ray),

(vi) evaluation of bone density: blood sample for calcium (Ca), phosphor (P), and magnesium (Mg) levels, protidemia, PTH, vitamin D3, and to carry out a vertebro femoral DEXA,

Table 2: Clinical followup in different age classes of PW patient.

	From birth to 3 years	From 3 to 10 years	From 10 to 18 years	Adult
Axiological evaluation	3-4 months	6 months	6–12 months	
Nutritionist/dietician evaluation	6–12 months	6–12 months	6–12 months	6–12 months
Blood sample (OGTT, HbA1c, total cholesterol and HDL, triglyceride level, uricemia, TSH, fT4, IGF1)	6 month	6–12 months	6–12 months	1 year
Evaluation of pubertal development (dosage of LH, FSH, estradiol (in females) and testosterone (in males) both basal and after GnRH)			According to clinical evaluation	
Bone age (left hand X-ray)		GH therapy: 1 year	According to clinical evaluation	
Evaluation of bone density				
Blood sample for Ca, P and Mg, protidemia, PTH, vitamin D3.		1-2 years	1-2 years	1-2 years
DEXA		1-2 years	1-2 years	1-2 years
Polysomnography	No GH therapy: 1 year GH therapy: 3–6 months	1 year	1 year	In case of problem
ENT with fibroscopy	No GH therapy: 6–12 months GH therapy: 3–6 months	In case of problem	In case of problem	
Orthopedic evaluation	1 year (consider the necessity of spine X-ray)	6 months (consider the necessity of spine X-ray)	6 months (consider the necessity of spine X-ray)	In case of problem
Orthoptic/ophthalmology evaluation	1 year	In case of problem	In case of problem	
Dental evaluation	Annual after 2 years	6 months	6 months	In case of problem
Dermatological evaluation		In case of skin picking	In case of skin picking	In case of skin picking
Echocardiography and cardiological evaluation				2 years
Neuropsychiatric and physiatric evaluation	3 months	1 year	1 year	1-2 years

OGTT: oral glucose tolerance test, DEXA: dual-energy X-ray photon absorptiometry; ENT: ear-nose-throat.

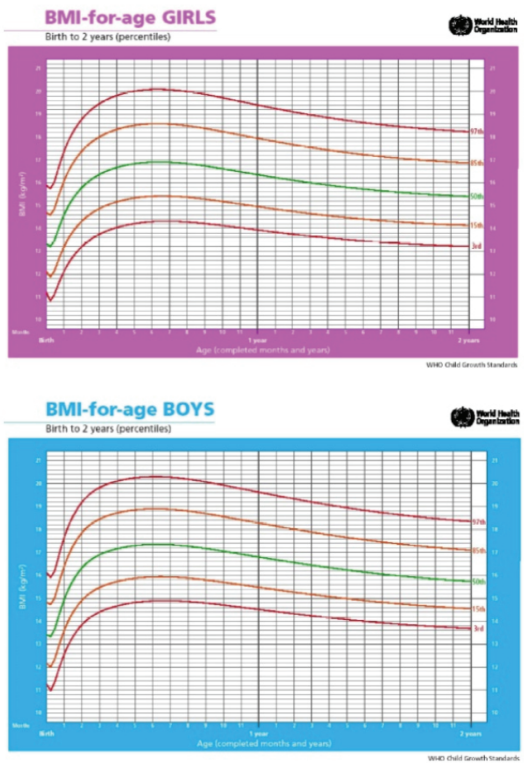

Figure 3: Standard BMI proposed by WHO from 0 to 2 years.

(vii) polysomnography and ENT with fibroscopy,

(viii) orthopedic evaluation,

(ix) orthoptic/ophthalmology evaluation,

(x) dental evaluation,

(xi) dermatological evaluation,

(xii) echocardiography and cardiological evaluation,

(xiii) neuropsychiatric and physiatric evaluation.

In consideration of the numerous problems that can take place during the PW patient's life, we have identified various age classes in which we define the best followup, that is resumed in Table 2.

6. Conclusion

Prader-Willi syndrome is a complex multisystem disorder. Patients can be affected by various problems; therefore precocious diagnosis is fundamental to guarantee optimal assistance. Each patient should undergo personally tailored treatment from birth. Therapeutic decisions and clinical followup need to consider all of these possible problems. A multidisciplinary team is required, made up of specialists such as neonatologists, geneticist, pediatricians, endocrinologists, orthopedic surgeons, psychologists, psychiatrists, physiotherapists, and urologists to deal with the numerous medical and psychological problems a PWS patient has to face. Only in this way we can improve quality of life, prevent complications, and prolong life expectancy in patients with PWS.

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