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Editorial Board

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Editorial

Sedentary Behaviors, Weight, and Health and Disease Risks

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Prior to the 1980s, very little thought was given to sedentary behaviors and how they may impact health. In 1985, the first study to investigate the relationship between a sedentary behavior, television viewing, and weight status was published by Dietz and Gortmaker [1]. In this study, the relationship between television viewing and weight status in children and adolescents was examined cross-sectionally and longitudinally, using data from the National Health Examination Survey. Results indicated that television viewing was positively related to the prevalence of obesity, both cross-sectionally and longitudinally. This investigation led to a growing body of research examining the mechanisms by which television watching impacted weight status and if reducing television watching could improve weight status in children. Outcomes from this area of research informed the development of the recommendation that screen time should be limited to ≤2 hours per day in children [2].

Initially, the term "sedentary" was used to describe behaviors that were not considered to meet energy expenditure levels equivalent to moderate-intensity physical activity. Additionally, attention was focused on sedentary behaviors occurring during leisure time, thus television viewing and recreational computer use were the sedentary behaviors that were predominantly reported in early investigations of sedentary behaviors. Since the 1980s, sedentary behaviors have become more clearly defined and are now classified by energy expenditure level, similar to the way that physical activities are classified. Sedentary behaviors are characterized by minimal movement and a very low level of energy expenditure (<1.5 metabolic equivalent units (METs)) similar to that which is required to sit quietly [3, 4]. Thus, sedentary pursuits are primarily sitting behaviors that occur in a variety of domains (i.e., leisure, occupation, transportation, and recreation) and include working/playing on the computer, driving a car, and watching television.

While sedentary behaviors have been associated with deleterious health outcomes in children for almost thirty years, sedentary behaviors are now also associated with morbidity in adults. Recent observational epidemiological research indicates that the more time spent being sedentary, independent of time engaging in physical activity, the greater the risk of developing type 2 diabetes [5], cardiovascular disease [5, 6], metabolic syndrome [7], weight gain [8–10], and obesity [11, 12]. Furthermore, evidence suggests that sedentary behaviors are an independent risk factor for all-cause and cardiovascular-related mortality [5, 13–15].

There are many proposed mechanisms by which sedentary behaviors may negatively influence health. For television watching, it was initially proposed that watching television may reduce energy expenditure, by competing with time to engage in physical activity, and increase energy intake, by serving as a cue for eating [16–19]. However, there is growing evidence suggesting that engaging in increased amounts of sedentary behaviors can have adverse effects on health that are distinct from those related to insufficient physical activity [4, 14, 20, 21]. Experimental studies show that prolonged sitting and lack of contraction of lower limb muscles lead to metabolic abnormalities via suppressed action of muscle lipoprotein lipase and insulin, supporting a unique "inactivity physiology" paradigm [20, 22–25]. Thus, sedentary behaviors may influence health via pathways that are independent of both physical activity and food consumption. Traditionally, while sedentary behaviors are believed to influence health through energy balance behaviors, the potential distinct mechanism by which sedentary behaviors may negatively influence health suggests that sedentary behaviors should potentially be targeted independently from physical activity and dietary intake in interventions designed to reduce risk type 2 diabetes, cardiovascular disease, and metabolic syndrome.

The purpose of this special issue is to explore some of the unresolved issues pertaining to sedentary behaviors, weight, and health and disease risk in children and adults. The papers in this special issue assist in broadening the understanding of the relationship between sedentary behaviors, weight, and health. The topics regarding sedentary behaviors addressed in this issue include assessment of sedentary behaviors, the relationship of sedentary behaviors with other health behaviors and outcomes, how energy expenditure during sedentary behaviors may be increased, and outcomes for interventions designed to reduce sedentary behaviors.

If experimental studies verify that sedentary behaviors are related to health outcomes that are public health priorities, continued research is needed to understand the pathways by which sedentary behaviors negatively impact health and how sedentary time can be reduced. Additionally, as the types and amount of sedentary behavior engaged in may be different in children versus adults due to differences in how time is spent and choices made about leisure-time activities, future research should investigate sedentary behaviors across the lifespan.

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Research Article

Beyond Screen Time: Assessing Recreational Sedentary Behavior among Adolescent Girls

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Most studies of sedentary behavior have focused on television use or screen time. This study aims to examine adolescent girls' participation in a variety of recreational sedentary behaviors (e.g., talking on the phone and hanging around), and their association with physical activity (PA), dietary behaviors, and body mass index. Data were from a sample of 283 adolescent girls. Recreational sedentary behavior, PA, and dietary behaviors were self-reported, and girls' height and weight were measured. Over 95% of girls engaged in at least one recreational sedentary behavior during the recall period. Watching television and hanging around were the most common behaviors. Watching television, using the Internet, and hanging around were associated with less PA; watching television, hanging around, and talking on the phone were associated with less healthful dietary behaviors. No associations were found with body mass index. Interventions may benefit from capitalizing on and intervening upon girls' common recreational sedentary behaviors.

1. Introduction

Physical inactivity among adolescents is believed to play a key role in their risk for obesity. While reducing sedentary behavior is an often-recommended strategy to prevent and treat obesity among adolescents [1, 2], studies aiming to understand associations between sedentary behavior and weight have almost exclusively focused on adolescents' television use [3–7], or the broader concept of screen time, which incorporates other technology-based activities such as computer and video game use [8–10]. This predominant attention to television use and screen time has called into question whether other types of sedentary behavior may displace physical activity (PA) and prompt unhealthful dietary intake, contributing to excess weight gain among adolescents [11].

Adolescent girls are a particularly important population in which to understand the associations between a range of sedentary behaviors and PA and weight as adolescent girls experience a significant decline in PA as they move through the adolescent years [12, 13] and are less likely to participate in vigorous PA than adolescent boys [14]. While watching television is a common leisure-time activity among adolescents, many adolescent girls report frequently participating in sedentary behaviors that are not screen-based yet still may pose a risk for excess weight gain, such as sitting and hanging around with friends, talking on the phone, and listening to music [11, 15, 16]. Additionally, for a significant proportion of adolescent girls, television, computer, and/or video game use are not their favored sedentary activities, and, therefore, these girls spend little time participating in screen-based activities but a great deal of time engaging in other sedentary behaviors [11, 15].

While there is increasing evidence that adolescent girls engage in a number of different sedentary activities that account for a large proportion of their day, only a small number of studies have utilized a comprehensive view of adolescent girls' sedentary behavior to examine associations between these behaviors and girls' PA, dietary intake, or weight status [17–21], and findings from these studies have been somewhat contradictory. For example, Leatherdale [17] observed that adolescent girls who were physically active were more likely to engage in "communication time," including talking on the phone, texting, and instant messaging, as well as frequently watching TV and movies and playing video or computer games. Meanwhile in a study of patterns of sedentary behaviors among adolescents, Gorely et al. [18] observed that girls who spent the majority of their leisure time participating in social activities including talking on the phone, hanging out, and talking with friends tended to watch relatively little television and were unlikely to meet recommendations for daily PA. Additional studies are needed with diverse samples of adolescent girls to better understand girls' sedentary behavior preferences, as well as whether participation in these behaviors is associated with girls' risk for obesity.

In light of the need for research examining associations between a wide range of sedentary behaviors and adole-scent girls' weight and weight-related behaviors, the current study aims to describe the frequency and duration of partici-pation in a variety of recreational sedentary behaviors (e.g. watching television, hanging around, talking on the phone, and Internet use) and identify associations between these recreational sedentary behaviors and body mass index (BMI), PA, and dietary behaviors, among a sociodemographically diverse population of overweight, obese, and/or sedentary adolescent girls. Recreational sedentary behaviors were selected as a focus because they characterize girls' use of their discretionary time as opposed to necessary sedentary pursuits such as doing homework and sleep. Study findings can aid in the identification of behavioral targets for interventions aiming to decrease sedentary time and promote PA and healthful dietary intake among sedentary adolescent girls, who are at risk for obesity and related health outcomes.

2. Methods

2.1. Study Design and Population. Data were drawn from the baseline evaluation of New Moves, a school-based intervention that aimed to prevent obesity and other weight-related problems among adolescent girls [22]. The population included 283 adolescent girls in grades 9 through 12 (mean age = 15.8 years; SD = 1.2). Twelve schools from 1 urban and 6 suburban school districts offered the New Moves program during either the 2007/2008 or 2008/2009 school years. To recruit girls to participate in the study, the New Moves intervention was described in the school course catalogue and on posters located around the school; recruitment materials were designed to appeal to girls who were currently overweight or obese and/or were inactive and not comfortable being physically active, but who had a desire to be healthier. A short screening questionnaire developed for the current study was used to assess girls' frequency and duration of PA/exercise and their frequency of use of disordered eating behaviors. Four girls were excluded from the intervention because of high levels of PA (≥1 hour/day). The study sample was sociodemographically diverse with 28% of girls identifying as African/American black, 28% white, 16% Hispanic, 18% Asian, and 11% of mixed or other race/ethnicity. Approximately, half of the girls were of normal weight status while 18% were overweight (age- and gender-adjusted BMI percentile between the 85th and 95th percentile), and 28% were obese (BMI percentile ≥95th). Across the 12 schools, between 22 and 92% of students were eligible for free or reduced-price school breakfast and lunch, and in 8 of the 12 schools over 55% of the students were eligible for free or reduced-price school breakfast and lunch. Girls completed baseline data collection during either the end of spring semester or beginning of fall semester preceding their participation in New Moves. Data collection occurred either at the University of Minnesota's General Clinical Research Center or at the participants' schools. Trained study staff oversaw all data collection with groups of up to 15 girls at a time. Staff reviewed all survey instruments for clarity and completeness at the time of the data collection. Two staff members edited survey instruments, and the data were entered and double checked for accuracy. The study was approved by the University of Minnesota's Institutional Review Board and by each participating school district. Participants provided written assent and parent consent.

2.2. Measures

2.2.1. Recreational Sedentary Behavior and Physical Activity. Girls' recreational sedentary behavior and PA were measured using the 3-Day Physical Activity Recall (3DPAR). The 3DPAR assessed the sedentary behaviors and physical activities that study participants engaged in during each half hour time block between 6 AM and midnight on the three days previous to the day of data collection. Girls completed the 3DPAR on a Monday, Tuesday, or Wednesday in order to capture at least 1 weekday and 1 weekend day. In order to complete the 3DPAR, participants were provided with a list of 65 common sedentary behaviors and physical activities and were asked to select the activity that they participated in for the majority of every 30-minute block. Girls' participation in recreational sedentary behavior was determined by the average daily number of 30-minute blocks in which girls' reported participating in the following activities: hanging around; listening to music (sitting); playing video games; surfing the Internet, instant messaging, emailing, shopping online; reading; watching TV or movies; talking on the phone [16, 23, 24].

To assess the frequency of girls' total PA and moderate-to-vigorous physical activity (MVPA), for each block of PA reported girls noted whether their exertion level while engaging in that activity was light, moderate, hard, or very hard. For every activity at each exertion level, a corresponding metabolic equivalent (MET) value was identified using the Compendium of Physical Activities [25, 26]. Total PA was defined as a per day average number of blocks for which any PA was reported. MVPA was defined as the per day average number of 30-minute blocks for which physical activities with a MET value greater than or equal to 3 were recorded [27, 28]. The 3DPAR has been shown to be a valid measure of MVPA as compared to accelerometry [27] and among adolescent girls had a 2-day test-retest reliability of $r = 0.71$ and $r = 0.77$ for MVPA and vigorous activity, respectively [29].

For recreational sedentary behaviors, total PA, and MVPA, girls' weekend and weekday behavior was weighted to reflect 2 weekend days and 5 weekdays and then divided by 7 to produce a daily average. The Previous-day Physical Activity Recall instrument, which is the same measure as the 3DPAR but collects one day of data regarding both sedentary behaviors and physical activities, has been determined to be a valid measure of screen time when compared to pedometer-measured activity [30].

2.2.2. Body Mass Index (BMI). Trained study staff measured girls' body weight using a Tanita Body Composition Analyzer TBF-300A (Tanita Corporation of America, Arlington Heights, Ill, USA) and height using a portable stadiometer. Girls' weight was measured twice, and both measurements were recorded to the nearest 0.1 kg. If between the two measurements there was a discrepancy of greater than 0.5 kg, the two measurements were repeated. Similarly, girls' height was measured twice, and both measurements were recorded to the nearest 0.1 cm. If there was a discrepancy of greater than 0.5 cm, the two measurements were repeated. The multiple measurements were then averaged to produce a single height and weight for each participant. BMI was calculated using the formula: weight in kilograms divided by height in meters squared, and BMI was transformed to age- and gender-specific z-scores according to the CDC's BMI-for-age and -gender growth charts.

2.2.3. Fruit and Vegetable Intake. Girls' fruit and vegetable intake was assessed using the questions, "Thinking back over the past week, how many servings of fruit did you usually eat on a typical day? A serving would be a medium piece of fruit. Do not include juice." and "Thinking back over the past week, how many servings of vegetables did you usually eat on a typical day? A serving would be 1/2 cup of cooked vegetables or 1 cup of raw vegetables. Do not include potatoes or French fries." Response options for both questions included "None," "Less than 1 serving," "1 serving," "2 servings," "3 servings," "4 servings," and "5 or more servings" [31, 32]. Two-week test-retest correlations for these items were 0.67 for fruit intake and 0.68 for vegetable intake.

2.2.4. Soft Drink Intake. Girls' intake of soft drinks was assessed with the following item: "Over the past month, how often did you drink regular soda pop (not diet)?" Response options included "Never," "Less than once a week," "1-2 times per week," "3-4 times per week," "5-6 times per week," "1 time per day," "2 times per day," "3 times per day," "4 times per day," "5 or more times per day." These response options were adapted from existing beverage intake items in the literature [33]. Two-week test-retest correlation for this item was 0.52.

2.2.5. Fast Food Intake. Girls' weekly intake of fast food was assessed with the question, "In the past week, how often did you eat something from a fast food restaurant (like McDonald's, Burger King, etc.)?" Response options included, "0 times," "1 time," "2 times," "3 times," "4-5 times," "6-7 times," "more than 7 times." This survey item was adapted from a previously existing measure [34] and had a 2-week test-retest correlation of $r = 0.81$.

2.3. Data Analysis. Girls who completed a 3DPAR on Monday through Wednesday and, therefore, reported their sedentary behaviors and physical activities for at least one weekday and one weekend day were included in the current study. Girls who completed the 3DPAR on Thursday or Friday were excluded as they did not recall any weekend days. Due to this selection criterion, the analytic sample for the current study represents 79.4% of all girls who participated in the New Moves evaluation trial (283/356). Day of completion of the 3DPAR was determined by the availability of the General Clinical Research Center, not characteristics of the girls, therefore, reducing the potential for selection bias. Descriptive statistics including the percent of girls reporting any participation in each of the recreational sedentary behaviors, and the median blocks of participation in each behavior for both the whole sample and the sample of girls who reported participating in each behavior were calculated for both weekdays and weekend days. To examine cross-sectional associations between girls' participation in each of the recreational sedentary behaviors and BMI z-scores, PA, and dietary habits, three levels of girls' daily participation in each behavior were created: none, low, and high. The low and high categories were created by dichotomizing the sample of girls who participated in each behavior at the median level of participation. To determine the three levels of girls' combined participation in all of the assessed recreational sedentary behaviors (low, moderate, and high), the summary variable was divided into tertiles. ANCOVA was used to calculate the mean level of the outcome variable for each of the three behavior participation levels, adjusted for girls' race/ethnicity and age. School was included as a random effect to account for potential clustering of girls' sedentary behavior by school. The P values presented are based on an F statistic with 2 degrees of freedom and a Tukey-Kramer adjusted P value was used to identify sources of differences between the adjusted means. SAS 9.2 (SAS Institute, Cary, NC, USA) was used for all analyses.

3. Results and Discussion

Watching television, hanging around, talking on the phone, and listening to music were the most common recreational sedentary behaviors reported by study participants (Table 1). Over half of girls reported watching television and/or hanging around on both weekdays and weekend days. Playing video games was the most infrequently reported of the assessed recreational sedentary behaviors with 8% of girls reporting playing video games on weekdays and 10% reporting playing video games on weekend days. Overall, almost all girls reported engaging in at least one of the recreational sedentary behaviors examined in this study on both weekdays and weekend days. Among those who reported participating in any recreational sedentary behavior, the median number of blocks of recreational sedentary behavior was 8.0 blocks on weekdays and 10.8 blocks on weekend days.

Table 1: Percentage of girls participating in recreational sedentary behaviors and time spent engaging in behavior on weekdays and weekend days.

	Weekdays			Weekend days		
	% (n) reporting behavior	Median (blocks/day) among all girls	Median (blocks/day) among girls reporting behavior	% (n) reporting behavior	Median (blocks/day) among all girls	Median (blocks/day) among girls reporting behavior
Watching TV	64.7 (154)	1.5	3.0	71.8 (171)	2.0	3.5
Hanging around	52.5 (125)	0.5	2.0	63.9 (152)	1.5	3.8
Talking on phone	46.6 (111)	0	2.0	48.7 (116)	0	2.0
Listening to music	39.5 (94)	0	1.3	47.1 (112)	0	1.5
Internet use	35.7 (85)	0	2.0	40.3 (96)	0	2.0
Reading	25.6 (61)	0	1.5	29.0 (69)	0	1.5
Playing video games	8.4 (20)	0	1.0	9.7 (23)	0	1.5
All recreational sedentary behaviors	95.0 (226)	7.0	8.0	96.6 (230)	10.3	10.8

Note: A block represents the majority of a 30-minute period.

Several of the recreational sedentary behaviors were associated with lower PA and MVPA, and less healthful dietary intake, in analyses adjusting for girls' ethnicity/race and age (Table 2). Time spent watching TV was inversely associated with total PA and MVPA ($P = 0.03$ for both). Girls who spent the most time watching TV during the recall period also reported the lowest fruit and vegetable intake (3.8 servings per day) while girls who did not report any TV use reported consuming 5.3 servings of fruits and vegetables per day ($P = 0.02$). High amounts of time spent hanging around, the second most commonly reported activity, were associated with less time spent in total PA ($P = 0.006$), higher soft drink intake ($P = 0.001$), and eating fast food more frequently ($P = 0.006$). For example, girls who reported the greatest amount of time hanging around during the recall period consumed fast food 1 time more per week on average compared to girls who did not report any hanging around. Amount of time spent talking on the phone was positively associated with soft drink intake ($P = 0.03$) but was not inversely associated with PA, whereas Internet use was inversely associated with both total PA and MVPA ($P = 0.03$ and $P = 0.003$, resp.). Reading was the only recreational sedentary behavior associated with healthful dietary behaviors; girls who reported high amounts of reading reported lower soft drink and fast food intake ($P = 0.02$ and 0.04, resp.). Higher total recreational sedentary behavior time was associated with lower MVPA, PA, and fruit and vegetable intake, as well as higher soft drink intake. Girls' BMI z-scores did not significantly differ by their recreational sedentary behavior participation.

Results of this study highlight both the variety of sedentary behaviors in which adolescent girls frequently participate, as well as the potential for many of these behaviors, alone or in combination, to contribute to lower PA levels and less healthful dietary intake. However, no associations were observed between girls' sedentary behavior and BMI. Findings from the current study align with those examining sedentary behavior patterns among adolescent girls [19, 35], especially those of Gorely et al. [15], who found that watching television and social sedentary activities, such as talking on the phone, were quite common among adolescent girls in the United Kingdom. Meanwhile, video game use and to a lesser extent Internet use was relatively uncommon. These consistent results across two different populations of girls suggest that messages about limiting Internet and video game time may not be highly relevant to the majority of adolescent girls. Interventions may be more successful at reducing sedentary behavior by capitalizing on girls' desire to engage in social activities including talking on the phone and hanging around with friends. Additionally, in the current sample, Internet use may be relatively low due to the lower socioeconomic status of many girls' families. Therefore, if Internet-based activities are an essential component of future interventions with diverse communities, care should be taken to ensure that study participants have consistent access to the Internet.

In the current study, many girls reported spending a large amount of time hanging around, which was associated with low levels of PA and poor dietary intake. A small number of other studies have also observed that many adolescent girls spend a significant amount of their day hanging around [16, 36, 37] although these studies did not examine whether hanging around was associated with other weight-related behaviors. During data collection, girls completing the 3DPAR were encouraged by study staff to not utilize the hanging around code unless they truly were not engaging in any other activity. Therefore, this time likely represents highly unstructured time and provides an opportunity for intervention. Future interventions aiming to increase adolescent girls' PA or improve their dietary intake may benefit from working with girls to substitute unstructured time spent hanging around with other enjoyable social activities that are more physically active or expose girls to healthier food choices. Girls may be especially receptive to this type of intervention activity because it does not emphasize limiting enjoyable sedentary behaviors such as watching television but focuses on finding ways to spend more time during the day with friends participating in enjoyable activities.

Table 2: Associations between recreational sedentary behaviors and BMI, physical activity, and dietary behaviors.

	%	BMI z-score (mean)	MVPA (blocks/day)	Total PA (blocks/day)	Fruit and vegetable intake (servings/day)	Soda intake (times/day)	Fast food intake (times/week)
Watching TV							
None	16.8	1.0	**3.3**^{ab}	**5.1**^{ab}	**5.3**^{a}	0.8	2.2
Low (0.1–2.7 blocks/day)	41.2	0.8	**3.5**^{a}	**5.4**^{a}	**4.2**^{ab}	0.9	1.9
High (>2.7 blocks/day)	42.0	0.9	**2.4**^{b}	**4.1**^{b}	**3.8**^{b}	0.8	1.4
$P_{df=2}$		0.46	**0.03**	**0.03**	**0.02**	0.70	0.10
Hanging around							
None	24.8	0.8	3.3	**5.3**^{a}	4.0	**0.5**^{a}	**1.4**^{a}
Low (0.1–2.0 blocks/day)	38.7	0.9	3.4	**5.4**^{a}	4.6	**0.7**^{a}	**1.4**^{a}
High (>2.0 blocks/day)	36.6	0.9	2.5	**3.8**^{b}	3.9	**1.2**^{b}	**2.3**^{b}
$P_{df=2}$		0.78	0.09	**0.006**	0.25	**0.001**	**0.006**
Talking on the phone							
None	39.9	1.1	2.9	5.0	4.1	**0.5**^{a}	1.5
Low (0.1–1.6 blocks/day)	31.1	0.7	3.5	5.3	4.2	**1.0**^{ab}	1.7
High (>1.6 blocks/day)	29.0	0.8	2.7	3.9	4.4	**1.1**^{b}	2.0
$P_{df=2}$		0.07	0.20	0.06	0.84	**0.03**	0.32
Listening to music							
None	36.6	0.9	2.8	4.3	4.3	0.9	1.9
Low (0.1–0.7 blocks/day)	33.2	0.8	3.6	5.4	4.0	0.8	1.7
High (>0.7 blocks/day)	30.3	0.8	2.6	4.6	4.2	0.8	1.5
$P_{df=2}$		0.90	0.08	0.13	0.75	0.90	0.39
Internet use							
None	46.2	0.8	**3.5**^{a}	**5.5**^{a}	4.4	0.7	1.6
Low (0.1–1.2 blocks/day)	26.9	0.9	**2.9**^{ab}	**4.9**^{ab}	3.8	0.9	1.8
High (>1.2 blocks/day)	26.9	0.9	**2.3**^{b}	**3.5**^{b}	4.1	1.0	1.8
$P_{df=2}$		0.76	**0.03**	**0.003**	0.39	0.56	0.86
Reading							
None	62.6	0.9	3.2	5.0	4.1	**0.9**^{a}	**1.9**^{a}
Low (0.1–0.9 blocks/day)	19.3	0.9	2.7	4.6	4.4	**1.0**^{a}	**1.9**^{a}
High (>0.9 blocks/day)	18.1	0.8	2.6	4.3	4.3	**0.3**^{b}	**1.0**^{b}
$P_{df=2}$		0.86	0.34	0.54	0.74	**0.02**	**0.04**
Playing video games							
None	86.1	0.8	3.0	4.8	4.1	0.8	1.7
Low (0.1–0.7 blocks/day)	8.8	0.9	3.3	5.0	4.7	1.0	2.0
High (>0.7 blocks/day)	5.0	1.4	2.6	3.9	4.9	1.0	1.4
$P_{df=2}$		0.26	0.81	0.68	0.41	0.79	0.75
All recreational sedentary behaviors							
Low (<6.3 blocks/day)	32.8	0.8	**4.1**^{a}	**6.4**^{a}	**4.8**^{a}	**0.5**^{a}	1.4
Moderate (6.3–10.3 blocks/day)	34.0	0.9	**3.2**^{a}	**5.1**^{a}	**4.1**^{ab}	**0.9**^{ab}	1.9
High (>10.3 blocks/day)	33.2	0.8	**1.7**^{b}	**2.8**^{b}	**3.6**^{b}	**1.1**^{b}	1.9
$P_{df=2}$		0.64	**<0.0001**	**<0.0001**	**0.04**	**0.01**	0.19

Notes: Regression models included girls' race/ethnicity and age.
Significant findings are emboldened.
For associations where the overall F statistic was significant ($P < 0.05$), post hoc comparisons of outcome-specific adjusted means were conducted. Adjusted means with different superscript letters are statistically significantly different using Tukey-Kramer adjusted P value < 0.05. For example, girls who reported high levels of hanging around reported significantly less total physical activity compared to girls who did not report hanging around or reported low levels of hanging around.

While several of the recreational sedentary behaviors examined in the current study were associated with lower levels of physical activity and less healthful dietary habits, no associations were observed between recreational sedentary behavior and girls' BMI z-score. This finding is consistent with other studies that have observed no association or a small association between participation in sedentary behavior and adolescents' weight status [38, 39]. One potential explanation for the lack of associations observed in the current study and others is that excess weight gain may be due to the accumulation of several less healthful behaviors (e.g., energy-dense diet, inadequate sleep, sedentary lifestyle), and, therefore, only weak associations are observed when examining the role of sedentary behaviors in weight status in isolation of other behaviors. For example, a recent study has observed that obesity risk was higher among adolescents who engaged in both low levels of physical activity and high levels of screen time [8]. Additionally, sedentary behaviors may only be associated with obesity risk among some individuals, such as those with a genetic susceptibility to obesity [40], leading to the observation of null associations between sedentary behavior and weight among the general population. Despite the inconsistency of associations reported in observational studies, sedentary behavior is still an important intervention target, and studies that have aimed to reduce sedentary activity have successfully led to decreases in adolescents' weight status [41–43].

A strength of the current study is its use of a sociodemographically diverse population of adolescent girls who were either currently overweight or obese, or at high risk for overweight due to having a highly sedentary lifestyle. There is a great need to develop relevant and enjoyable programs that encourage greater participation in healthful PA and healthy eating behaviors among this population. However, this focus on a specific, underserved population does limit the generalizability of study findings, and the sedentary behavior patterns of highly physically active adolescent girls may be different than what was observed in this study population. An additional strength of this study is the use of the 3DPAR, which allowed for an understanding of the context of girls' sedentary time. While objective measures of PA and sedentary behavior, such as accelerometry, play an important role in obtaining an unbiased assessment of PA, use of self-report measures that record the specific activities that study participants are engaging in can provide great richness to the understanding of how individuals are spending their time. A limitation of the 3DPAR is that participants are only able to report a single activity that they participate in for the majority of each 30-minute block. Therefore multitasking, which adolescents do frequently when watching television [44], or behaviors that participants engaged in for less than 15 minutes, were not recorded with this instrument. This may result in an underestimation of participation in some behaviors. Additionally, girls completed the 3DPAR using a set list of common activities. Because this list was not comprehensive, activities that may be increasingly common, such as texting, were not captured by the instrument. However, it is important to note that girls rarely asked how to categorize texting during the data collection process, as they were often texting for short amounts of time throughout the day and not for the majority of a 30-minute time period. Girls who did ask how to code their texting time were told to categorize it with Internet use/instant messaging, which may have inflated the assessment of the amount of time girls spent on the computer. Future studies utilizing the 3DPAR are encouraged to conduct extensive pilot testing of the measure and adapt the activity options provided based on the popular activities among the intended study population.

4. Conclusions

Adolescent girls participate in a number of recreational sedentary behaviors for a significant portion of their free time. Understanding these patterns of behavior, and associations between recreational sedentary behaviors and PA and dietary habits, is informative to the development of interventions aiming to decrease adolescents' risk for overweight and obesity. Findings from the current study suggest that interventions developed to engage adolescent girls may benefit from incorporating messages and behavioral targets that address recreational sedentary behaviors such as hanging around, talking on the phone, and listening to music, in addition to the often-targeted watching television. Future research in this area is also needed to understand whether girls' participation in specific recreational behaviors contributes to decreases in PA and poor dietary intake, or whether the behaviors co-occur and are markers of a less healthful lifestyle in total. Additionally, in light of the lack of associations observed in the current study between recreational sedentary behavior and BMI, and the inconsistent findings between sedentary behavior and weight observed elsewhere in the literature [38, 45], further investigations of the role of television, screen time, and other common recreational sedentary behaviors in adolescents' weight and excess weight gain are a priority.

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Research Article

Accuracy of Intensity and Inclinometer Output of Three Activity Monitors for Identification of Sedentary Behavior and Light-Intensity Activity

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Purpose. To examine the accuracy of intensity and inclinometer output of three physical activity monitors during various sedentary and light-intensity activities. *Methods*. Thirty-six participants wore three physical activity monitors (ActiGraph GT1M, ActiGraph GT3X+, and StepWatch) while completing sedentary (lying, sitting watching television, sitting using computer, and standing still) light (walking 1.0 mph, pedaling 7.0 mph, pedaling 15.0 mph) intensity activities under controlled settings. Accuracy for correctly categorizing intensity was assessed for each monitor and threshold. Accuracy of the GT3X+ inclinometer function (GT3X+Incl) for correctly identifying anatomical position was also assessed. Percentage agreement between direct observation and the monitor recorded time spent in sedentary behavior and light intensity was examined. *Results*. All monitors using all thresholds accurately identified over 80% of sedentary behaviors and 60% of light-intensity walking time based on intensity output. The StepWatch was the most accurate in detecting pedaling time but unable to detect pedal workload. The GT3X+Incl accurately identified anatomical position during 70% of all activities but demonstrated limitations in discriminating between activities of differing intensity. *Conclusions*. Our findings suggest that all three monitors accurately measure most sedentary and light-intensity activities although choice of monitors should be based on study-specific needs.

1. Introduction

Physical inactivity is a leading preventable cause of all-cause mortality [1] and has been identified as one of the most important public health problems of the 21st century [2]. Physical inactivity has traditionally been considered the absence of physical activity at the moderate-to-vigorous intensity level which mistakenly combines the large portion of time individuals spend engaged in sedentary behaviors and light-intensity activities.

Sedentary behavior is defined as those activities that do not increase energy expenditure substantially above the resting level (i.e., 1.0–1.5 metabolic equivalent units (METs) [3] and includes activities such as sleeping (0.95 METs), lying down (1.0–1.3 METs), sitting watching television (1.3 METs), sitting at a computer doing light office work (1.5 METs), and standing still quietly (1.3 METs) [4]. Light-intensity physical activity has been described as activities that result in energy expenditure at the level of 1.6–2.9 METs such as walking slower than 2.0 mph (2.0 METs), cooking food (2.0 METs), and washing dishes (1.8 METs) [4].

Recent research has begun to explore more deeply into specific health implications associated with prolonged sedentary behaviors. For instance, in a cross-sectional study of 1,958 older men and women residing in Australia, both self-reported sitting time and television viewing time were associated with increased risk for metabolic syndrome [5]. In a subsample of the same study ($n = 168$), objectively measured sedentary time (via accelerometer) was found to be independently associated with increased waist circumference and risk for metabolic disease [6], whereas more breaks in sedentary time were beneficially associated with waist circumference, body mass index (BMI), triglycerides, and 2h plasma glucose [7]. Consistently, objectively assessed sedentary time (via physical activity monitors) has also been associated with increased biomarkers of chronic diseases (e.g., BMI, waist circumference, C-reactive protein, fasting insulin, and homeostasis model assessment of insulin resistance) in a sample of postmenopausal women [8]. Recent evidence that suggests replacing 30 minutes/day of sedentary time with light-intensity physical activity is associated with better physical health and overall well-being [9] highlights the need to have a thorough understanding of the differences between sedentary and light-intensity activity.

While evidence accumulates implicating reduced sedentary time as a target for interventions, there is still disagreement as to best practices for measuring sedentary behaviors. Although methods for measuring physical activity have become more sophisticated, methods for measuring sedentary behaviors lag behind. Early efforts to estimate sedentary time utilized self-report measures, which are critical for assessing population trends and effectiveness of public health interventions. However, self-report measures are often limited in their accuracy due to self-report bias and often do not target all sedentary behaviors [10]. Further, many self-report measures of sedentary time focus on specific activities such as television viewing time, limiting the interpretation of findings [10].

Objective measures, such as physical activity monitors, which have traditionally been utilized to measure physical activity of light-to-vigorous intensity, offer functionality that can also be used to measure sedentary behaviors. For example, as technology develops, new physical activity monitors are becoming available that have unique features (e.g., location, software analysis features, inclinometer, etc.) that may allow for better assessment of sedentary behavior. However, different physical activity monitors also have unique limitations and standardized procedures are still in development. For instance, there remains disagreement with regards to appropriate thresholds for calculating sedentary behavior.

Two physical activity monitors that have been widely used to date include the StepWatch physical activity monitor (Orthocare Innovations, Mountlake Terrace, Wash, USA) and ActiGraph accelerometer-based activity monitors (ActiGraph LLC, Pensacola, Fla, USA). ActiGraph has been on the forefront of accelerometry technology and has developed multiple models of physical activity monitors including previously demonstrated [11–14] single-axis GT1M and the more recent triaxial GT3X+ model which has unique functionalities, some of which have yet to be extensively tested.

Evidence of the validity of the ActiGraph accelerometer-based activity monitor to assess levels of moderate-to-vigorous physical activity has been presented [11–14], but limited research has examined the validity of the ActiGraph for assessment of sedentary behavior. Matthews et al. applied a threshold of <100 counts/minute from ActiGraph accelerometer-based activity monitors to a large representative sample from the 2003-2004 NHANES data set to represent sedentary behavior. The study authors reported that participants spent 55% of their time (approximately 7.7 hours/day) engaged in sedentary behaviors [15]. The GT1M was also recently demonstrated to correlate significantly, but modestly with self-reported sedentary activities (watching television (TV), computer use, reading, socializing, transport and hobbies, and a summary measure (total sedentary time)) amongst 48 older adults [16].

The tri-axis ActiGraph GT3X+ accelerometer-based activity monitor offers a unique combination of both vector magnitude calculation, allowing for measurement of physical activity intensity in three separate planes, and inclinometer functionality, allowing for the identification of anatomical position (e.g., lying down, sitting, standing). Kozey-Keadle et al. recently reported a correlation between directly observed sedentary minutes and sedentary minutes from the GT3X using the 100 counts/minute threshold of 0.62. Their results suggested that a threshold of 150 counts/minute provided a better assessment of sedentary behavior, relative to direct observation [17]. However, to date, the validity of the GT3X+ vector magnitude and inclinometer functions for distinguishing between sedentary and light intensity activities has yet to be demonstrated.

The StepWatch physical activity monitor is worn on the ankle, as opposed to the hip placement of the ActiGraph, allowing for possible differences in its ability to measure sedentary and physically active behaviors. Evidence of the accuracy and validity of the StepWatch has previously been demonstrated during controlled laboratory settings for measuring walking behavior and estimating energy expenditure [18, 19], although the ability of the StepWatch to distinguish between sedentary, light- and moderate-intensity activities is also unknown.

Currently, there are few valid objective measures for assessing sedentary behaviors. It is necessary to test the accuracy of the available physical activity monitors for their ability to accurately distinguish between the spectrums of physical activity intensities. Therefore, the primary aim of the present study was to examine the accuracy of intensity output of three physical activity monitors (GT3X+, GT1M, and StepWatch) for measurement of sedentary behavior and light-intensity activities under controlled settings. A secondary aim was to examine the accuracy of the inclinometer output of the GT3X+ monitor for measurement of anatomical position. We anticipated all three monitors to be accurate for measurement of sedentary activities under controlled settings. We also anticipated differences between the monitors for accurately measuring pedaling activities of light and moderate intensity due to differing placement (hip versus ankle) of the three physical activity monitors. It is anticipated that the findings of this study will provide researchers a guide for choosing appropriate monitors for the measurement of sedentary behavior and light-intensity activities in future studies.

2. Materials and Methods

2.1. Subjects. A total of 36 healthy, college-aged adults (age = 23.0 ± 3.7 years; BMI = 23.8 ± 3.8 kg/m^2; 55% female) were recruited for participation (see Table 1) and completed all study requirements. The BMI's of the included sample ranged from 19.7 to 39.1 kg/m^2 with 30.5% of the sample categorized as overweight/obese. Completion of the study

Table 1: Demographic characteristics of sample ($n = 36$).

	Mean	St. dev.
Age (years)	23.0	3.7
Height (cm)	171.2	9.5
Weight (kg)	70.6	15.8
BMI (kg/m^2)	23.8	3.8
Female (%)	55.0%	
Racial group (%)		
American Indian/Alaskan Native	0.0%	
Asian	2.8%	
Native Hawaiian or other Pacific Islander	0.0%	
Black or African American	19.4%	
White	69.4%	
Do not know/refuse	8.3%	
Ethnicity (%)		
Hispanic	2.0%	
Non-Hispanic	68.0%	
Do not know/refuse	30.0%	

was defined as wearing three physical activity monitors during six consecutive activities under controlled settings. Participants were devoid of any ambulatory limitations that would prevent them from engaging in the activities for eight consecutive minutes. Participants were not compensated for participation in this study. Experimental protocols were approved by the University and Medical Center Institutional Review Board at the authors' institution and voluntary informed consent was obtained from each participant.

2.2. Experimental Design. All testing assessments were conducted during the months of March and April 2011. Following the informed consent, participants were asked to attend one 60-minute testing session. During this session, participants were asked to complete a series of six consecutive activities that varied in both movement (i.e., no movement, walking, and pedaling) and anatomical position (i.e., lying, sitting, and standing). Activities were identified as either sedentary or light intensity according to the most recent Physical Activity Compendium [4]: (1) lying still with legs straight and flat on back in a horizontal position (estimated 0.9 METS); (2) sitting relaxed but upright in a chair while watching television with feet on floor (estimated 1.0 METS); (3) sitting relaxed but upright in a chair with feet on the floor while using a computer (estimated 1.5 METS); (4) standing upright, while completely still (estimated 1.2 METS); (5) walking very slowly at 50 steps/min or roughly 1.0 mph (estimated 2.0 METS); (6) pedaling on a magnetic resistance pedal exercise machine (MagneTrainer; 3D Innovations, LLC, Greeley, CO) at either a slow pace (7.0 mph; $n = 19$) or a self-selected pace (recorded mean = 15.0 mph; $n = 17$). The activities used in this study were chosen to represent a range of activities (sedentary lying down to low-intensity cycling) that are often performed in free-living environments (lying down, TV viewing, computer use, and walking), but differed distinctly in both movements (no movement versus walking versus cycling) and anatomical positions (lying down, sitting, and standing).

Walking was guided by a metronome set at 50 steps/min and participants were observed walking at this pace. All participants were instructed to pedal at a constant speed guided by a speedometer on the MagneTrainer. Participants who pedaled at self-selected speeds were instructed to identify a "comfortable" pedal pace within the first two minutes and remain at that pace for the remainder of the activity. The resistance level of the pedal machines was consistent for both pedaling cadences. The intensity of the two pedal cadences was confirmed as light intensity based on both heart rate and rating of perceived exertion (RPE) data with a pilot sample ($N = 10$) of participants of a similar age (23.5 years) to the study sample.

Each activity lasted eight minutes in duration with two-minute breaks in between each activity. All participants were instructed to complete each task in the same anatomical position. To address protocol fidelity (i.e., to ensure 100% time participants spent in each activity was true to the activity), activities were observed directly and the first and last minute of each activity were removed from analyses leaving six minutes for each activity.

To allow analysis of the same activity by multiple assessments, participants completed the six activities while wearing three different physical activity monitors: (1) the ActiGraph GT3X+; (2) the ActiGraph GT1M; (3) the StepWatch. These three monitors were purposefully tested to compare multiple monitors of differing placement (hip versus ankle) and functionality (e.g., step rate, accelerometry, and inclinometer) with the hope of adding to the knowledge based on specific monitors that are best suited for measuring specific sedentary and light-intensity activities. For example, many physical activity intervention studies encourage walking [20] while others encourage cycling [21]. It is important that researchers choose objective monitors that most accurately assess the primary activity being promoted or measured. Participants wore the two ActiGraph monitors on a belt over their left or right hips and the StepWatch on either their left or right ankle. The locations of all three monitors were counterbalanced to result in an equal number of participants wearing each monitor on the left and right sides of their body.

The StepWatch was initialized based on the participant's self-reported height and steps per minute were recorded. The GT1M monitor was initialized at 1-second epochs and reintegrated to 60-second epochs to calculate counts per minute to remain consistent with the StepWatch. The GT3X+ monitor was initialized at a frequency of 30 Hz and counts/min was then calculated to remain consistent with the other two monitors. The low-frequency extension (LFE) was not selected when initializing the GT3X+. Minutes spent in each of the six different activities were then separated by each monitor to allow for specific monitor/activity analyses. Summary files were then created to calculate the total number of minutes out of six minutes correctly recorded as either sedentary behavior (lying down, sitting watching television, sitting and typing on computer, and standing still) or light intensity (walking slowly at 1.0 mph, pedaling at 7.0 or 15.0 mph).

The thresholds used for each monitor are provided in Table 2. The sedentary threshold used for the StepWatch (zero) was based on the recommendation provided by the product manufacturer (StepWatch). The thresholds for light- (1–45 steps/min) and moderate- (46+ steps/min) intensity physical activity used for the StepWatch were based on previous work which demonstrated moderate-intensity stride rate to range from 90–113 steps/minute depending on height and stride length [22, 23].

Based on results from Kozey-Keadle et al., two different thresholds (i.e., <100 counts/minute and <150 counts/min) were used for calculating sedentary time from the GT1M (GT1M100, GT1M150) and GT3X+ (GT3X+100, GT3X+150) monitors [17]. Counts per minute were collected from the single axis for the GT1M and from the vector magnitude for the GT3X+ monitors. No thresholds for sedentary have been established for the GT3X+. Previously established thresholds developed on the GT1M [15, 17] were used to categorize activities as either light or moderate intensity for both the GT1M and GT3X+ monitors.

The GT3X+ inclinometer function (GT3X+Incl) was tested for its ability to accurately identify anatomical positions (i.e., lying down, sitting, and standing) during the six activities, which is not a direct measure of the intensity of the activity. Manufacturer recommendations were followed to categorize each minute of activity into an anatomical position (i.e., 1 for standing, 2 for lying down, 3 for sitting, and 0 for nonwear).

2.3. Statistical Analysis. Validity of the activity monitors/thresholds was examined by comparing the monitor-recorded time (total minutes out of six minutes) coded as sedentary behavior, light intensity, or moderate intensity with the criterion of direct observation. For the GT3X+Incl function, validity was examined by comparing the monitor recorded time (total minutes out of six minutes) coded as lying down, sitting, standing and/or non-wear with the criterion of direct observation. Specifically, percentage of agreement was defined as the percent agreement between the criterion measure of observed intensity or anatomical position minutes and the monitor-recorded intensity or anatomical position minutes. The 95% confidence interval was calculated for the mean minutes out of 6 minutes correctly coded for both intensity and anatomical position. Significance was determined based on whether the 95% confidence interval spanned the criterion of 6 minutes correct. Root mean square error for minutes of sedentary behaviors (lying down, sitting watching television, sitting using computer, and standing) and light-intensity activities (walking 1.0 mph, pedaling 7.0 mph, pedaling 15.0 mph) coded correctly out of 6 minutes was calculated for both intensity and inclinometer outputs. While statistical analyses were performed on minutes, data are reported as percent time coded in each intensity/anatomical position.

3. Results

The sample included healthy, college-aged adults of normal- to obese-weight status (BMI range = 19.7–39.1 kg/m^2) and a roughly even gender distribution (see Table 1). Participants were primarily White (69.4%) or Black/African American (19.4%) and the majority were non-Hispanic (68.0%).

When examining the minutes correctly identified as sedentary, all three physical activity monitors accurately identified over 80% of all sedentary activities (lying down, sitting watching television, sitting using computer, and standing still) as sedentary using multiple thresholds for sedentary behavior (see Figure 1, Table 3).

When examining minutes correctly identified as light intensity, all three monitors/thresholds accurately identified at least 70% of all walking minutes as light intensity with the exception of the GT1M150 (60.7%). The StepWatch was the most accurate identifying 88.8% of slow walking time as light intensity, whereas the GT1M150 was the least accurate (60.7% agreement). For the pedaling activities, the StepWatch was the only monitor to accurately record more than half of all pedaling time at 7.0 mph (54.4%) and 15.0 mph (100%) as "nonsedentary". However, 45.6% of pedaling time at 7.0 mph was incorrectly coded as sedentary and 60.8% of pedaling time at 15.0 mph was incorrectly coded as moderate intensity with the StepWatch.

The inclinometer function of the GT3X+ correctly identified anatomical position between 60.6 and 66.7% of the time during the four sedentary activities (see Table 4). The GT3X+Incl also accurately identified 71.8% of light-intensity walking time as standing, 85.1% of pedaling at 7.0 mph as sitting, and 74.5% of pedaling at 15.0 mph as sitting. Across all sedentary and light-intensity activities, the GT3X+Incl coded less than 14.3% of all wear time as zero or "non-wear".

Root mean square error for minutes correctly coded as sedentary behavior and light-intensity activity are presented in Table 5. Root mean square error was lowest for the GT1M150 (0.07) and highest for the GT3X+100 monitor (0.86) during sedentary behaviors while root mean square error was lowest for the GT1M150 (2.10) and highest for the StepWatch monitor (3.33) during light-intensity activities. The root mean square error was consistently larger for light-intensity activities as compared to sedentary behaviors across all monitors for intensity outputs. Root mean square error for correctly identifying minutes in anatomical position was larger during sedentary behaviors than light-intensity activities for the GT3X+Inclinometer function (see Table 5).

4. Discussion

The findings from this study support the StepWatch, GT1M, and GT3X+ physical activity monitors as accurate measures of time spent sedentary based on intensity output during such activities as lying down, sitting watching television, sitting using computers, and standing still under controlled settings. When comparing average accuracy for correctly coding the four sedentary behaviors across all monitors/thresholds, the GT1M monitor was the most accurate when using the <150 counts/min threshold (average 99.2%) followed by the GT1M at the <100 threshold (average 98.4%), the StepWatch (average 96.2%), GT3X+ vector magnitude at the <150 threshold (average 90.1%), and the GT3X+

TABLE 2: Thresholds for intensity and anatomical positions for each physical activity monitor.

	Sedentary	Light intensity	Moderate intensity
StepWatch	0 steps/min	1–45 steps/min	46+ steps/min
GT1M100	0–99 counts/min	100–2220 counts/min	2221+ counts/min
GT1M150	0–149 counts/min	150–2220 counts/min	2221+ counts/min
GT3X+100	0–99 counts/min	100–2689 counts/min	2690+ counts/min
GT3X+150	0–149 counts/min	150–2689 counts/min	2690+ counts/min
GT3X+Incl	Coded 1 = standing still	Coded 1 = walking	
	Coded 2 = lying down	Coded 3 = sitting pedaling	
	Coded 3 = sitting TV/computer	Coded 0 = Non-wear	
	Coded 0 = Non-wear		

vector magnitude at the <100 threshold (87.0%). While statistical significance was often detected when comparing the monitor-recorded times against the criterion of 100% accuracy, such findings should be interpreted with caution. Small differences are often statistically significant due to large sample size and small sample variation. For example, monitors that were highly accurate at identifying a particular intensity had very little variability on the identified activity codes. The agreement between the activity recorded by the monitors and the directly observed criterion measures provides a guide for researchers trying to choose the best measure of sedentary time. Overall, these findings support the use of all three physical activity monitors for assessing time spent sedentary with little difference between thresholds of 100 and 150 counts/min.

All three monitors also appear to be fairly accurate in identifying slow walking at 1.0 mph as light-intensity activity. With the exception of the GT1M when using the 150 counts/min threshold, all monitors/thresholds accurately identified over 70% of all slow walking time as light intensity. It appears that the GT1M was less accurate when using the <150 counts/min threshold to discriminate between sedentary behaviors and light-intensity activities. This example, however, illustrates an important point in that measurement of physical activity intensity depends on the chosen threshold and researchers should be aware that there is a trade-off with using such thresholds. For example, when comparing the two thresholds used for discriminating between sedentary and light-intensity activity (<100 and <150 counts/min) for the GT1M and the GT3X+, it appears that expanding the definition of sedentary to all activities under 150 counts/minute increases the percent agreement slightly for sedentary activities for both monitors which is consistent with previous studies [17]. Specifically, the GT1M and GT3X+ monitors accurately identified an average of 99.2% and 90.1% of all sedentary minutes when using the 150 counts/min thresholds, respectively.

Percent agreement for identifying walking as light-intensity dropped 10% for the GT1M when using the 150 counts/min threshold compared to the 100 counts/min threshold, while the percent agreement for the GT3X+ was nearly identical for both thresholds. Therefore, the effect of changing the activity count threshold may be that the

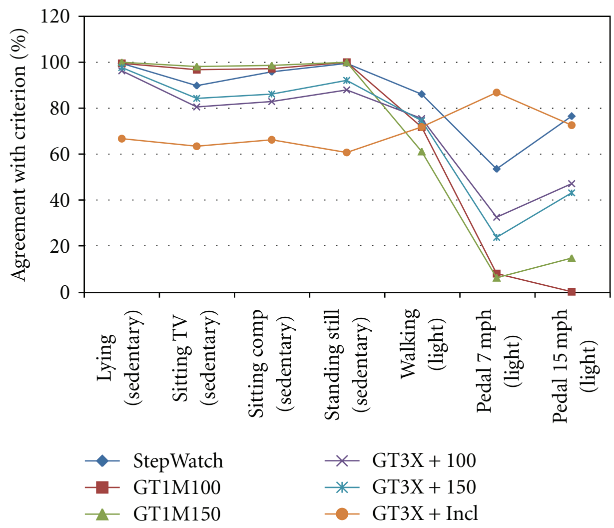

FIGURE 1: Concurrent time interval of mean percent agreement for intensity (StepWatch, GT1M100, GT1M150, GT3X+100 and GT3X+150) and anatomical position (GT3X+Incl) across all activities.

accuracy of time spent in one intensity category (e.g., sedentary) improves, while the accuracy of identifying time spent in the adjacent category (e.g., light-intensity) is sacrificed. Additionally, it is possible that the accuracy of specific thresholds is dependent upon additional factors, such as levels of adiposity, and these potential influences should be explored.

Additionally, specific to the Actigraph monitors, measurement of sedentary time is also dependent upon specific features such as the low-frequency extension (LFE), which is intended to broaden the low-frequency range of the digital band-pass filter allowing for more sensitive detection of movement. Although the LFE was not enabled in the present study, the GT3X+ appears to be more sensitive to movement than the single-axis GT1M. This suggests that different thresholds for sedentary behavior may be appropriate for the two monitors. Based on the present findings it appears that 100 counts/min is more appropriate for the GT1M, whereas 150 counts/minute provides slightly more accurate identification of sedentary behavior and light-intensity activity than the 100 counts/min threshold for the

Table 3: Percent time coded as sedentary behavior, light intensity, moderate intensity, and mean coded correctly (±95% CI) for each monitor/threshold and activity.

Stepwatch	Correct code	Mean coded correct (%)	95% confidence interval	% coded sedentary	% coded light	% coded moderate
Lying down	Sedentary	99.5	98.6–100.5	99.5	0.5	—
Sitting TV	Sedentary	89.8	82.9–96.7	89.8	10.2	—
Sitting computer	Sedentary	95.8	92.7–99.0	95.8	4.2	—
Standing	Sedentary	99.5	98.6–100.5	99.5	0.5	—
Walking (1.0 mph)	Light	86.1	76.8–95.4	3.8	88.8	7.4
Pedaling 7.0 mph	Light	54.4	35.7–73.1	45.6	54.4	0.0
Pedaling 15.0 mph	Light	23.5	8.8–38.3	0.0	39.2	60.8
GT1M100						
Lying down	Sedentary	99.5	98.6–100.5	99.5	0.5	—
Sitting TV	Sedentary	96.8	93.8–99.7	96.8	3.2	—
Sitting computer	Sedentary	97.2	94.7–99.7	97.2	2.8	—
Standing	Sedentary	100.0	100.0–100.0	100.0	0.0	—
Walking (1.0 mph)	Light	71.8	59.4–84.1	28.2	71.8	0.0
Pedaling 7.0 mph	Light	8.1	−2.5–18.6	92.1	7.9	0.0
Pedaling 15.0 mph	Light	15.5	0.8–30.1	88.5	11.5	0.0
GT1M150						
Lying down	Sedentary	100.0	100.0–100.0	100.0	0.0	—
Sitting TV	Sedentary	98.2	96.4–100.0	98.2	1.8	—
Sitting computer	Sedentary	98.6	97.0–100.2	98.6	1.4	—
Standing	Sedentary	100.0	100.0–100.0	100.0	0.0	—
Walking (1.0 mph)	Light	61.1	47.7–74.5	39.3	60.7	0.0
Pedaling 7.0 mph	Light	6.6	−4.0–17.1	93.9	6.1	0.0
Pedaling 15.0 mph	Light	14.7	0.0–29.4	85.3	14.7	0.0
GT3X+100						
Lying down	Sedentary	96.3	93.0–99.6	96.3	3.7	—
Sitting TV	Sedentary	80.6	69.7–91.4	80.6	19.4	—
Sitting computer	Sedentary	82.9	74.7–91.0	82.9	17.1	—
Standing	Sedentary	88.0	80.6–95.3	88.0	12.0	—
Walking (1.0 mph)	Light	75.5	64.3–86.6	18.0	75.5	6.5
Pedaling 7.0 mph	Light	33.2	18.5–47.9	67.5	32.5	0.0
Pedaling 15.0 mph	Light	47.1	26.5–67.6	52.0	47.1	0.9
GT3X+150						
Lying down	Sedentary	97.7	95.3–100.1	97.7	2.3	—
Sitting TV	Sedentary	84.3	74.4–94.2	84.3	15.7	—
Sitting computer	Sedentary	86.1	79.5–92.8	86.1	13.9	—
Standing	Sedentary	92.1	85.7–98.5	92.1	7.9	—
Walking (1.0 mph)	Light	74.5	62.5–86.6	19.0	74.5	6.5
Pedaling 7.0 mph	Light	23.7	8.9–38.4	76.3	23.7	0.0
Pedaling 15.0 mph	Light	43.1	21.7–64.6	55.9	43.1	1.0

GT3X+. These findings are consistent with recent findings by Kozey-Keadle et al [17].

When examining pedal activity, consistent with our hypothesis, the ankle-worn StepWatch was the only monitor to identify more than half of pedaling time as nonsedentary. This makes intuitive sense as both ActiGraph monitors are worn on the hip and past studies have confirmed waist-mounted pedometers to be less sensitive to lower-extremity pedaling activity than ankle-worn monitors such as the StepWatch [24]. Still, while the StepWatch was able to pick up more pedal activity than the Actigraph monitors, the StepWatch can only code intensity based on pedal rate rather than workload. This is illustrated in the present study by the large discrepancy in intensity identification between the two pedal rates of 7.0 and 15.0 mph which were performed at the same low resistance. These findings indicate

Table 4: Percent time anatomical position was coded correctly (±95% confidence interval) and incorrectly (as lying, sitting, standing, or non-wear) for the GT3X+ Inclinometer for each activity.

GT3X+Incl	Correct code	Coded correct (%)	95% conf. interval	Position coded lying (%)	Position coded sitting (%)	Position coded standing (%)	Position coded "non-wear" (%)
Lying down	2 = lying	66.7	52.2–81.2	—	13.9	5.1	14.3
Sitting TV	3 = sitting	63.4	50.5–76.4	0.0	—	30.1	6.5
Sitting computer	3 = sitting	66.2	53.3–79.1	0.9	—	23.6	9.3
Standing	1 = standing	60.6	46.3–75.1	0.0	37.5	—	1.9
Walking 1.0 mph	1 = standing	71.8	59.7–83.8	0.0	28.2	—	0.0
Pedaling 7.0 mph	3 = sitting	85.1	69.7–100.4	3.5	—	11.4	0.0
Pedaling 15.0 mph	3 = sitting	74.5	54.4–94.6	0.0	—	19.6	5.9

Table 5: Root mean square error for minutes of sedentary behaviors (lying down, sitting watching television, sitting using computer, standing) and light intensity activities (walking 1.0 mph, pedaling 7.0 mph, pedaling 15.0 mph) coded correctly out of 6 possible minutes.

	StepWatch	GT1M100	GT1M150	GT3X+100	GT3X+150	GT3X+Incl
Sedentary behaviors	0.33	0.13	0.07	0.86	0.68	2.15
Light Intensity activities	3.33	2.49	2.10	2.84	2.81	0.98

that although the ankle-worn StepWatch may be the most accurate of the three monitors at measuring low-intensity pedaling activity, a large portion of time spent pedaling at 15.0 mph was inaccurately coded as moderate intensity while a large portion of pedaling time at 7.0 mph was inaccurately coded as sedentary behavior. Researchers are encouraged to supplement StepWatch data with another measure of intensity such as heart rate or rating of perceived exertion (RPE) to better distinguish between sedentary behaviors and light-intensity behaviors.

When assessing the accuracy of the GT3X+Incl for measuring time spent in each of the three anatomical positions (e.g., lying down, sitting, and standing), our findings indicate that the inclinometer accurately identified anatomical position more than 60% of the time during sedentary behaviors. Our findings suggest the inclinometer function to be more accurate at identifying the correct position during sedentary activities of sitting and standing and less accurate at measuring time spent lying down than previously reported [25]. Further, the inclinometer function was more accurate at identifying the correct anatomical position during light-intensity activities (71.8–85.1% percent agreement) than during sedentary activities. It appears that the inclinometer is most accurate during times of more movement which seems to result in less time coded as "non-wear".

While the inclinometer offers unique functionality in that it allows for differentiating between time spent in various anatomical positions, researchers should be cautious when using this feature. For example, when using the intensity output of the GT3X+ during pedaling time, more than half of all time was inaccurately identified as sedentary while the inclinometer accurately identified more than 74% of this same time as "sitting". Under controlled settings, the researcher could easily identify the times spent pedaling and code this time as nonsedentary but when such monitors are used in the field, without an additional measure of intensity such as heart rate monitors, the researcher would have no way of determining whether this time was sedentary or nonsedentary. This is further illustrated in the present study when comparing time spent standing still versus time spent standing and walking slowly. The GT3X+ intensity output accurately identified these times as sedentary and light intensity, respectively, whereas the inclinometer function could not distinguish between the two different activities. In summary, it seems that if researchers are interested in using the inclinometer output to identify anatomical position during sedentary behavior, our data indicate the inclinometer function only identifies roughly two-thirds of time in the correct anatomical position. Therefore, further work is warranted to identify an appropriate way to use both the intensity and the inclinometer output of the GT3X+ in combination.

The present study has several limitations. First, the findings presented are limited to the sample of relatively lean college-aged adults. The findings are also limited to the types of sedentary and light-intensity activities completed and the positions participants were in while completing each activity. For example, while sitting using the computer, participants were instructed to sit upright in a chair with their feet flat on the floor. While this is a likely position an individual would sit in while using a computer, it is possible that different results would be found if a person were sitting in a different position. This study is also limited by the vector magnitude thresholds used to estimate sedentary time for the GT3X+ monitor. Currently, no vector magnitude threshold for sedentary behavior has been established, but based on our findings, both 100 and 150 counts/min seem to provide similar results for the examined activities.

5. Conclusions

Overall, all three physical activity monitors tested in this study appear to accurately identify time spent in sedentary behaviors and engaged in slow walking under controlled settings when using the intensity output. However, discrepancies appear between the monitors when measuring lower-extremity pedaling time with the ankle-worn StepWatch being the most accurate but still limited by an inability to assess pedal resistance. The GT3X+Incl seems to accurately identify anatomical position during 70% of all sedentary and light-intensity activities although this feature is also limited in its ability to distinguish between activities conducted in similar anatomical position but of differing intensity. It is recommended that researchers interested in measuring sedentary and light-intensity time use monitors with specific features that best suit the targeted activities.

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Research Article

The Feasibility of Reducing and Measuring Sedentary Time among Overweight, Non-Exercising Office Workers

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This study examined the feasibility of reducing free-living sedentary time (ST) and the convergent validity of various tools to measure ST. Twenty overweight/obese participants wore the activPAL (AP) (criterion measure) and ActiGraph (AG; 100 and 150 count/minute cut-points) for a 7-day baseline period. Next, they received a simple intervention targeting free-living ST reductions (7-day intervention period). ST was measured using two questionnaires following each period. ST significantly decreased from 67% of wear time (baseline period) to 62.7% of wear time (intervention period) according to AP ($n = 14$, $P < 0.01$). No other measurement tool detected a reduction in ST. The AG measures were more accurate (lower bias) and more precise (smaller confidence intervals) than the questionnaires. Participants reduced ST by ∼5%, which is equivalent to a 48 min reduction over a 16-hour waking day. These data describe ST measurement properties from wearable monitors and self-report tools to inform sample-size estimates for future ST interventions.

1. Introduction

Sedentary behavior is defined as energy expenditure between 1–1.5 metabolic equivalents (METs) while sitting or reclining [1] and accounts for the majority of occupational, transportation, and discretionary time [2]. Using data from the National Health and Nutrition Examination Survey, Matthews et al. reported that 54% of waking hours were sedentary [3]. Among healthy, predominantly overweight individuals, 62%–68% of waking hours are spent in sedentary behaviors [4]. A growing body of evidence shows that sedentary time is associated with an increased risk of obesity, chronic disease, and mortality [1]. However, to date, the majority of evidence linking sedentary behavior to adverse health consequences is cross-sectional [5–7], from which causality cannot be determined. However, a recent review by Thorp et al. [8] concluded that there is some prospective evidence that supports relationships between sedentary behavior, mortality, and health outcomes. Studies have shown that sedentary time is associated with increased risk for type II diabetes [9–11] and mortality [12]. Other studies report no association or suggest reverse causality between sedentary time, obesity, and insulin resistance [13, 14]. Studies often failed to adjust for physical activity and BMI, which may explain the disparate results [8]. In addition, the majority of these studies used surrogate measures of sedentary time (e.g., TV viewing) and self-report measures, which may not accurately measure sedentary time.

Sedentary time is frequently estimated from surrogate measurements such as time spent watching television (TV) [10, 12, 15]. Robust positive relationships have been reported between TV viewing and poor health outcomes including risk of diabetes and premature mortality [16]. However, TV viewing is also associated with increased energy intake, and markers of poor health that may confound the association between sedentary time and metabolic health [17, 18]. Furthermore, while TV viewing is correlated with sedentary time among unemployed individuals, it is not for those who are employed suggesting that TV viewing may be a poor surrogate measure for overall sedentary time [19]. Self-report questionnaires, including those that measure domain-specific [20] and single-item [21] sitting time, are also available. A recent review by Healy and colleagues suggests that existing questionnaires may be acceptable for establishing cross-sectional associations but may not be acceptable for prospective or intervention trials [22]. The authors note a paucity of data on the absolute agreement of sedentary time estimates from self-report questionnaires, and few studies have compared sedentary time questionnaires to a valid criterion measure [22].

Activity monitors are attractive tools to measure sedentary time. To date, though, few studies (i.e., 3 of 48 included in the Thorp review) have used activity monitors for sedentary behavior research [8]. The ActiGraph (AG), using the cut-point of 100 counts$\cdot$min^{-1} (AG100), is the most commonly used objective tool to assess sedentary time. Previous research from our laboratory showed that the activPAL (AP) activity monitor is more accurate, precise, and sensitive to detecting changes in sedentary time than AG using a number of sedentary time cut-points ranging from 50 to 250 counts$\cdot$min^{-1} [23]. However, our validation results were based on two, 6-hour direct observation sessions, and do not include factors such as day-to-day variability that is important to quantify for intervention studies designed to decrease sedentary time. To date, no studies have used the AP, a criterion measure of sedentary time [24], to compare the validity of existing measurement tools over a 7-day period or to assess the ability of existing measurement tools to detect *changes* in free-living sedentary time.

While an abundance of evidence suggests that sedentary time is associated with poor health outcomes, we do not know the feasibility of reducing sedentary time, the validity of existing measurement tools over a 7-day period, or the ability of existing measurement tools to detect changes in free-living sedentary time [22, 25]. This study addressed these knowledge gaps with the following three aims. First, we determined if a simple one-week sitting time intervention decreased sedentary time as measured by the criterion AP among nonexercising, overweight/obese individuals with sedentary occupations. We compared sedentary time pre- and postintervention for the total week and for weekend and weekdays. Second, we compared whether or not existing questionnaires and activity monitors detected reductions in sedentary time following the 7-day intervention. Third, we compared the convergent validity of the AP, the AG, and the questionnaires.

2. Methods

2.1. Participants. Participants were recruited from the University of Massachusetts, Amherst, and local communities. Eligible participants were between 20 and 60 years of age, overweight or obese with a body mass index (BMI) between 25 and 45 kg$\cdot$m^{-2}, inactive (i.e., participating in moderate-to-vigorous physical activity [MVPA] <3-days per week for <20 minutes per session in the preceding six months), and employed in jobs where the majority of their day was sedentary (i.e., participants self-reported over 75% of their work day as sedentary). Potential participants completed a telephone screening to determine eligibility.

2.2. Study Protocol

2.2.1. Visit 1. Eligible participants reported to the laboratory at the University of Massachusetts for an informed consent visit. Participants read and signed an informed consent document (ICD) that was approved by the Institutional Review Board at the University of Massachusetts. After signing the ICD, height and weight were measured. The average (SD) age was 46.5 (10.8) years and BMI was 33.7 (5.6) kg$\cdot$m^{-2}. Seventy-five percent (15/20) of the participants were female. Participants were shown the activity monitors (described below) and were provided with detailed verbal and written instructions on proper monitor placement. They were instructed to wear the monitors for a 7-day period while maintaining habitual activity levels. This was the *baseline period*.

2.2.2. Visit 2. After wearing the monitors for 7 days, participants returned to the laboratory, and the activity monitor data were downloaded. Participants completed two self-report questionnaires (described below) with questions about sitting time during the previous 7 days (*baseline period*).

2.2.3. Intervention. A researcher provided the participant with information about the potential health risks associated with sedentary time and the benefits associated with increasing light-intensity activity. Participants were given a packet that contained a list of strategies to reduce sedentary time and a checklist to monitor sedentary time for each of the next 7 days. The document outlining strategies to reduce sedentary time included an extensive list of ways to replace sedentary time with light-intensity activity. They are the following:

At Home

(i) Walk while talking on the phone.

(ii) Walk your dog an extra 10 minutes each day.

(iii) Do dishes by hand instead of using the dishwasher.

(iv) Stand during commercials (remain standing an extra minute after).

(v) Do a little extra housework.

(vi) When grocery shopping, walk up and down each isle, even doing it twice to walk longer and to pick up grocery items you may have forgotten the first time.

(vii) Walk up and down stairs a couple times a day.

(viii) When you are carrying things in from the car (e.g., groceries) take more frequent trips with only one bag at a time.

(ix) Walk to get the mail, instead of driving by shovel instead of using a snow blower.

(x) Mow your lawn (even better get a nonmotorized mower).

(xi) Wash your car (no drive through!).

At Work

(i) Stand to answer telephone.

(ii) Take a 5-minute walk/stand break each hour.

(iii) Hand-deliver a message to a coworker instead of emailing.

(iv) Take the stairs (start with walking 2 floors then taking elevator if your building is tall).

(v) Use restroom on a different floor.

(vi) Eat your lunch outside or somewhere other than your desk.

Recreation and Transportation

(i) Choose active recreation instead of going to a movie (e.g., bowling, pool, and darts).

(ii) Volunteer to plant trees or start a garden at home.

(iii) Volunteer to walk a dog, play with kids in need, or help habitat for humanity.

(iv) Take the bus or other public transportation when possible.

(v) Go for a hike or a picnic instead of going for a scenic drive.

The packet also included a form asking participants about specific barriers in their free-living environment that would inhibit reductions in sedentary time. They were then counseled on specific ways to overcome those barriers. In addition, they were given a daily checklist reminding them to break up sedentary time by reporting if they stood or walked for five or more minutes for each hour of the day. Finally, participants were provided a pedometer to wear for the next 7 days and given a goal of attaining 7500 steps/day, the lower boundary for "somewhat active" behavior [26]. Participants were instructed to accumulate the steps in 5–15 minute bouts over the course of the day rather than one large bout of activity. Participants were instructed to wear the AG and AP activity monitors for another 7-day period and were asked to follow the recommendations to reduce sedentary time. This was the *intervention period*.

2.2.4. Visit 3. Participants returned the monitors on the third visit and completed the same two self-report questionnaires completed at visit one. These questionnaires asked about time spent sedentary in the previous 7 days (*intervention period*). After completing the questionnaires, participants were asked the following questions about the intervention period: "Was the pedometer step per day goal helpful in meeting your goals? Why or why not?", "Was the daily checklist helpful for meeting your goals?", and "Did you fill out the checklist (circle the one that best applies)" (1) once a day (2) as you completed activity (3) every couple of days (4) once in the week.

2.3. Measurements

2.3.1. ActivPAL Activity Monitor (PAL Technologies, Glasgow, Scotland, UK). This is a small (2.0 × 1.4 × 0.3 inches) and light (20.1 grams) uniaxial accelerometer-based device that was worn anteriorly on right mid-thigh and held in place by nonallergenic adhesive tape. This device uses accelerometer-derived information about thigh position to estimate time spent in different body positions (i.e., sitting/lying, standing and stepping). Data were collected for a one-week period and processed in 15-second epochs using activPAL software (version 5.8.3). We previously validated the activPAL monitor for measuring free-living sedentary time in the same subjects as the current study [23]. The activPAL was valid and precise with a bias of 2.8% and an R^2 value of 0.94 compared to direct observation [23]. The monitor was also sensitive to reductions in sedentary time [23]. In a laboratory-based validation Grant et al. [24] reported a mean percentage difference between sedentary time from the monitor and direct observation of 0.19% and the mean difference for total time spent upright was −0.27%.

2.3.2. ActiGraph GT3X Activity Monitor (Actigraph LLC, Pensacola, Fla, USA). This is a small (1.5 × 1.44 × 0.7 inches) and light (28 grams) accelerometer that was worn on the right hip and secured by an elastic belt. The monitor was initialized using ActiLife software version 4.2 and firmware version 2.1.0. The monitor was initialized to record vertical accelerations in 1-second epochs with the low-frequency extension option activated. Count cut-points of 100 counts·min^{-1} (AG100) and 150 counts·min^{-1} (AG150) were used to define sedentary time. The Freedson cut-point of 1952 counts·min^{-1} was used to define moderate to vigorous physical activity (MVPA) [27].

2.3.3. Omron Pedometer HJ720-ITC (Omron Healthcare, Bannockburn, Ill, USA). Pedometers have been used to provide referent goals for individuals to estimate activity levels. For example, <5000 steps/day is sedentary, 5000–7499 steps/day is low active, and >10,000 steps/day is active [26]. The pedometer provided a self-monitoring tool to facilitate compliance with sedentary reduction recommendations, but since pedometer steps are not a direct measure of sedentary time, it was not considered in the primary analyses.

2.3.4. Total Sitting Questionnaire (T-SQ). The short-version of the International Physical Activity Questionnaire (IPAQ) was used to assess usual time sitting in total number of hours and minutes per day for both work and nonwork days [21]. The question reads, "How many hours did you spend sitting down while doing things like visiting friends, driving, reading, watching TV, or working at a desk or computer on a typical workday in the last week." In a sample of 744 adults, the test-retest reliabilities for the sitting items from this questionnaire ranged from $r = 0.18$ to $r = 0.95$ and criterion validity compared to the AG100 had low to moderate agreement ($r = 0.07$ to $r = 0.61$) [21].

2.3.5. Domain-Specific Questionnaire (D-SQ). This questionnaire asks about time spent sitting in hours and minutes on a typical weekend day and weekday over the past 7 days in each of five domains: transportation, watching television, at work, using a computer at home, and leisure time not including television (e.g., visiting with friends). The test-retest reliability and convergent validity compared to the AG100 for the five sitting domains range from $r = 0.31$ to $r = 0.91$ and $r = 0.13$ to $r = 0.74$, respectively. Both reliability and validity were lower for weekend days compared to weekdays [20]. To score the data, the sum of the sitting times from the five domains was used to represent daily sitting time.

2.3.6. TV Viewing (TV-Q). The TV viewing question from the DS-Q was used to determine total time watching television. The question reads "please estimate how many hours per day you spend sitting while watching television."

2.4. Monitor Log and Wear Time. All participants recorded details about monitor wear in a log used to determine monitor wear time. Participants were asked to record the time they woke up in the morning, the time they put the monitors on, the time they took the monitors off, and the time they went to bed. They were also asked to indicate any times they took the monitors off during the day for greater than ten minutes. To be included in the analyses, a participant was required have at least four days of monitor wear for at least ten hours each within each period [28].

2.5. Statistical Evaluation. Twenty participants completed the study protocol. One participant was excluded from all analyses, because the participant sat in a seat where the thigh was perpendicular to the floor while seated. This resulted in erroneous standing time estimate from the AP tool. All statistical analyses were performed using R (www.r-project.org). Significance levels were set at $P < 0.05$. The data were graphically examined using q-q plots and histograms to confirm normality.

2.5.1. Effect of the Intervention: Primary Outcome Measure AP. To eliminate the effect of different wear times, we computed the percentage of wear time that was sedentary (i.e., (sedentary hours/total wear time)∗100) for each day. A repeated measures linear mixed model was then used to compare the differences in percent sedentary time pre- to postintervention. A separate model was also fit for percent stepping, percent standing, breaks per day (i.e., sit-to-stand transitions), steps per day, and wear time. We also examined the differences pre- to postintervention for week and weekend days separately. Likelihood ratio tests were used to determine if the difference in each outcome measure pre- to postintervention was significant.

2.5.2. Sensitivity to Change. A repeated measures linear mixed model and likelihood ratio tests were used to analyze the differences pre- to postintervention in percent sedentary time for the AG100 and AG150. A paired t-test was used to examine the differences pre- to postintervention for T-SQ, D-SQ, and the TV-Q. We also assessed the sensitivity and specificity for each measure compared to the AP. Based on the AP, an individual was classified as a responder (reduced sedentary time) or nonresponder (did not reduce sedentary time) during the intervention period compared to the baseline period. There was no minimum amount of change required to count as a responder. We then identified responders and nonresponders to the intervention for each of the other measures and categorized them based on the following criteria.

(1) True positives: The individual was a responder according to both the AP and the measure.

(2) True negative: The individual was a nonresponder according to both the AP and the measure.

(3) False positive: The individual was a nonresponder according to the AP but was a responder according to the measure.

(4) False negative: The individual was a responder according to the AP but was a nonresponder according to the measure.

Sensitivity was calculated as the true positives/(true positives + false negatives)∗100. Specificity was calculated as the true negatives/(true negatives + false positives)∗100. The 95% confidence intervals (CI) were calculated for both sensitivity and specificity.

2.5.3. Convergent Validity. For the third aim, we assessed the validity of the questionnaires, AG100 and AG150 for measuring baseline sedentary time per day with the AP serving as the criterion measure. Since the questionnaires ask about weekend and weekdays separately, we examined weekend and weekdays separately for the activity monitors.

We assessed bias and precision to determine validity. Bias is the average difference of the estimate from the measure (AG100, AG150, T-SQ, and D-SQ) and the AP sedentary time (minutes). A positive bias indicates the measure overestimates sedentary time, and a negative bias indicates the measure underestimates sedentary time. Precision is the inverse of variability or random error, which was examined using confidence intervals and Pearson correlations. Higher precision was indicated by higher correlations and smaller confidence intervals. For the TV-Q, we assessed the Pearson correlation between AP daily sitting and TV-Q but did not assess bias, since the TV-Q does not produce an estimate of overall sedentary time.

3. Results

3.1. Efficacy of the Intervention

3.1.1. Changes Pre- to Postintervention. Participants significantly reduced sedentary time according to the AP from 67.0% of wear time in the baseline period to 62.7% of wear time in the intervention period ($P < 0.05$) (Table 1). Stepping time and steps per day significantly increased, there

Table 1: ActivPAL outcome measures pre- and postintervention.

	All days		Weekday		Weekend	
	Baseline period	Intervention period	Baseline period	Intervention period	Baseline period	Intervention period
% Sedentary	67.0 ± 13.3	62.7 ± 11.9*	69.4 ± 11.1	65.6 ± 9.5*	61.0 ± 16.3‡	55.9 ± 14.2
% Standing	23.2 ± 9.7	25.6 ± 9.7	21.4 ± 8.3	23.3 ± 8.0	27.5 ± 11.6‡	31.0 ± 11.4
% Stepping	9.8 ± 5.0	11.7 ± 4.3*	9.1 ± 4.0	11.1 ± 3.7*	11.5 ± 6.7‡	13.1 ± 5.2
Breaks per day	53.2 ± 21.0	49.2 ± 17.1*	56.2 ± 22.4	53.6 ± 17.3	46.0 ± 15.4‡	38.6 ± 11.4*
Steps per day	6417 ± 3366	8167 ± 3600*	6121 ± 2495	8133 ± 3101*	7132 ± 4871	8247 ± 4650
Daily wear time (hrs)	14.1 ± 1.9	14.1 ± 2.0	14.1 ± 1.98	14.3 ± 2.0	14 ± 1.7	13.7 ± 2.1

Note: % Sedentary, % Standing, and % Stepping expressed as percent of wear time (e.g., (total sedentary time/wear time)∗100).
Data includes 14 participants with valid data during both the baseline and intervention period.
‡Significantly different from weekdays during baseline period.
*Significantly different in intervention condition compared to baseline condition ($P < 0.05$).

Table 2: Monitor and questionnaire sedentary time, sensitivity, and specificity using the AP as the criterion measure.

		Baseline period mean ± SD	Intervention period mean ± SD	Sensitivity (95% CI)	Specificity (95% CI)
Weekday	AP (% Sedentary)	68.8 ± 8.5	65.1 ± 6.5*	—	—
	AG100 (% Sedentary)	66.4 ± 10.2	62.9 ± 10.5	80 (53, 100)†	67 (39, 94)
	AG150 (% Sedentary)	70.5 ± 9.4	67.1.4 ± 10.1	70 (43, 97)	67 (39, 94)
	T-SQ (hours/day)	9.3 ± 3.3	8.2 ± 4.4	80 (53, 100)†	33 (06, 61)
	D-SQ (hours/day)	12.6 ± 2.9	11.6 ± 2.2	70 (43, 100)†	33 (06, 61)
	TV-Q (hours/day)	2.3 ± 1.85	2.5 ± 1.75	20 (0, 47)	100 (73, 100)†
Weekend	AP (% Sedentary)	60.4 ± 15.6	57.3 ± 12.1	—	—
	AG100 (% Sedentary)	62.7 ± 8.9	64.4 ± 7.3	67 (38, 95)	71 (43, 100)†
	AG150 (% Sedentary)	66.7 ± 9.0	69.0 ± 6.2	57 (29, 85)	80 (52, 100)†
	T-SQ (hours/day)	6.2 ± 3.1	6.0 ± 3.3	57 (29, 85)	60 (32, 88)
	D-SQ (hours/day)	12.1 ± 5.0	10.7 ± 3.9	57 (29, 85)	60 (32, 88)
	TV-Q (hours/day)	3.4 ± 2.14	3.3 ± 1.60	43 (15, 71)	100 (72, 100)†

Note: AP is activPAL, AG100 is ActiGraph cut-point of 100 counts$\cdot$min^{-1}, AG150 is ActiGraph 150 cut-point of 150 counts$\cdot$min^{-1}, T-SQ is total daily sitting questionnaire, D-SQ is domain specific questionnaire, TV-Q is the D-SQ question specifically about TV viewing.
Data included 13 participants with valid data for all measures during both the baseline and intervention period.
AP, AG100, and AG150 are expressed as a percentage (total sedentary time/wear time) to adjust for differences in wear time.
*Indicates statistically significant difference between conditions $P < 0.01$.
†Indicates significant sensitivity or specificity ($P < 0.05$).

was a decrease in breaks per day, and there was no significant change in standing time (Table 1). Three participants wore the AP monitor upside down on four or more days of a condition resulting in invalid data for those individuals. For two participants, the AP monitor stopped prematurely and recorded less than two days of data during one condition, leaving a total sample of $n = 14$ with valid AP data both pre- and postintervention.

3.1.2. Differences between Weekend and Weekdays. At baseline, participants were less sedentary, stood more, had more stepping time, and took fewer breaks from sitting on weekend days compared to weekdays according to the AP ($P < 0.01$). There was no significant difference in steps per day between weekend and weekdays. On weekdays, sedentary time decreased from 69.5% of wear time in the baseline period to 65.6% of wear time in the intervention period ($P < 0.05$). This change pre- to postintervention is equivalent to a 37-minute reduction over a 16-hour waking day. On weekend days, sedentary time was 60.9% of wear time in the baseline period, and it was 55.9% of wear time in the intervention period. This is equivalent to a 48.6 minute reduction over a 16-hour waking day but was not a statistically significant change ($P = 0.2$).

3.2. Device and Questionnaire Sensitivity to Change. Neither AG measure (AG100 or AG150) was able to detect a statistically significant difference in sedentary time between the baseline and intervention period (Table 2). None of the questionnaires detected significant differences between the baseline and intervention period either (Table 2). To allow for a direct comparison across the measures, this analysis was done for only the individuals who had valid data for all the measures (AP, AG, and questionnaires). For this analysis, only participants with valid data from the AP, AG, and the questionnaires at both time points were included. Six individuals did not have valid AP data at both time points and were excluded. One AG monitor did not record a week's worth of data, leaving a total sample of 13 individuals for this analysis. However, since the power to detect change is smaller with the smaller sample size, we also examined the difference between conditions in all participants for the AG ($n = 19$) and questionnaires ($n = 20$), and the differences remained nonsignificant.

Of the 13 subjects with valid data for all measures, there were ten responders on weekdays and seven responders on weekend days according to the AP measure of sedentary time. The sensitivity, specificity, and CI's for each measure compared to the AP are shown in Table 2. The sensitivities for the AG100 and AG150 for weekdays were 80% (CI: 50%, 100%) and 70% (CI: 43%, 97%), respectively. Specificity on weekdays was 67% (CI: 39%, 94%) for both AG100 and AG150. Sensitivity was nominally lower (67% and 57%), and specificity was nominally higher (71 and 80%) for AG100 and AG150, respectively, on weekend days compared to weekdays. Those differences were not statistically significant ($P > 0.05$).

The sensitivities and specificities for all questionnaires for weekdays and weekend days ranged from 20% to 80% and from 33% to 100%, respectively. TV-Q had the lowest sensitivity but the highest specificity among the questionnaires. Both the DS-Q and T-SQ had higher sensitivity for weekdays. The sensitivity and specificity measures were lower for weekdays than weekend days for T-SQ and D-SQ, but the opposite was true for TV-Q (Table 2). Those differences were not statistically significant ($P > 0.05$).

3.3. Convergent Validity. For the monitors, we compared bias and precision overall (total week) and for weekend and weekdays separately. For the overall week, the bias (95% CI) for the AG100 was −3.8 min, (−29 to 22.2 min). That is not significantly different from unbiased. The AG150 significantly overestimated sedentary time 31.7 min (7.1 to 56.3 min).

3.3.1. AG Weekend and Weekday. For weekdays, the AG100 significantly underestimated sedentary time by 40 min (−69.7 to −8.3 min), and there was no significant difference between the AP and AG150 with an average difference of 1.4 min, (−29 to 31.9 min). The correlation on weekdays between the AP and AG100 was ($r = 0.52$) ($P < 0.05$), and between the AP and AG150, it was ($r = 0.55$) ($P < 0.05$).

For weekend days, the bias was 20.8 min (−32 to 74 min) for the AG100. The AG150 significantly overestimated sedentary time with a bias of 58.3 min (6.7 to 93.1 min) on weekend days. AP estimates of sitting were correlated with the AG150 ($r = 0.68$) and the AG100 ($r = 0.68$) for weekend days ($P < 0.05$).

3.3.2. Questionnaires. The T-SQ underestimated sitting time, but it was not significantly different than the AP for weekdays, with an average difference of 40.5 min (−125.2 to 22.3). The correlation was not statistically significantly different from zero ($r = 0.41$). The estimate of sitting time from the T-SQ was 147.4 min (−228.3 to −66.6) less than the AP for weekend days ($P < 0.05$). The correlation between sitting time from the T-SQ and AP was significant for weekend days ($r = 0.55$) ($P < 0.05$).

The D-SQ significantly overestimated sitting time for both weekend and weekdays. On weekdays, the D-SQ overestimated sitting time by 176 min (96.1 to 256.9 min). Similarly, on weekend days, sitting time was overestimated by 157.6 min (22.1 to 293.0 min). The correlation between the AP and D-SQ was not significant for either or weekdays ($r = 0.30$) or weekend days ($r = 0.17$). The correlation between the AP and TV-Q was not significant for either weekdays ($r = 0.07$) or weekend days ($r = -0.11$).

4. Discussion

This study addressed two important knowledge gaps in the field of sedentary behavior and health. First, it provides empirical evidence that it is possible to reduce free-living sedentary behavior among overweight and obese, nonexercising adults. Participants decreased sedentary time by ∼5%, which is equivalent to 48 minutes over a 16-hour waking day. Second, this study identified a measurement tool that is sensitive to change in sedentary behavior and provided a comparison of two commonly used accelerometer-based monitors and two self-report questionnaires.

4.1. Feasibility of Sedentary Behavior Intervention. To date, only two published intervention trials targeting sedentary time reductions are available in adults [29, 30]. Our results are similar to these trials despite differences in the study sample demographics, intervention targets, and measurement tools. Otten et al. targeted TV viewing among overweight and obese individuals who watch TV >3 hours per day and showed a 3.8% decrease in sedentary time [29]. Their study targeted only one sedentary domain (TV viewing) and the primary outcome was percent of time in sedentary activities according to the Sensewear arm band [29]. Gardiner and colleagues [30] completed a similar study to the current one. They included older adults who completed a 7-day baseline period followed by a 7-day intervention targeting sedentary time. They reported a 3.2% decrease in sedentary time [30]. They did not exclude participants who were participating in MVPA at baseline, and occupational sitting was not a target for their intervention, since many participants were retired. The primary outcome measure was the AG100 estimate of sedentary time [30]. To our knowledge, our study is the first to show a significant reduction of free-living sedentary time using a targeted intervention among nonexercising office workers and the first to use the AP monitor as an objective tool to assess sedentary time in an intervention study. Participants replaced sedentary time by increasing stepping ($P < 0.01$) and standing time ($P = 0.06$). Breaks from sedentary time significantly decreased in the intervention period, which is of concern given the evidence that more breaks from sitting may be beneficial for metabolic health [22]. However, since sedentary time was replaced with standing, there will naturally be less opportunity for sit-to-stand transitions. Thus, in future research, both breaks

Table 3: Individual responsiveness to intervention for each measure.

Individual	Week days						Weekend days					
	AP	AG100	AG150	T-SQ	D-SQ	TV-Q	AP	AG100	AG150	T-SQ	D-SQ	TV-Q
1	+	+	+	+	+	−	+	+	+	+	−	−
2	+	+	+	+	+	−	+	+	+	−	+	+
3	+	+	+	+	+	−	−	−	−	−	−	−
4	+	+	+	+	−	−	−	−	−	−	−	−
5	−	−	−	−	−	−	+	−	−	+	+	+
6	+	+	−	+	+	−	+	+	+	+	+	+
7	+	+	+	+	−	−	*NA	*NA	*NA	*NA	*NA	*NA
8	+	−	+	+	+	−	−	−	−	−	−	−
9	−	−	−	−	−	−	+	−	−	−	−	−
10	+	−	−	−	−	+	+	+	+	−	−	−
11	−	−	−	−	−	−	+	+	+	+	+	−
12	+	+	+	−	+	+	−	−	−	−	−	−
13	+	−	−	+	+	−	−	−	−	−	−	−

Note: + represents responder (reduced sedentary time pre- to postintervention) and − represents nonresponders (did not reduce sedentary time pre- to postintervention) for each individual.
AP refers to activPAL monitor, AG100 refers to the ActiGraph cut-point of 100 counts$\cdot$min^{-1}, AG150 refers to the ActiGraph cut-point of 150 counts$\cdot$min^{-1}, T-SQ is a single-item total sedentary time questionnaire and D-SQ is a 5-domain sedentary time questionnaire. TV-Q refers to D-SQ question about TV-viewing only.
*NA = no valid AP data for weekend.

from sitting and changes in absolute sedentary time must be used as outcome measures in evaluation of effectiveness of interventions designed to reduce sedentary time.

4.2. Intervention Strategies. At the end of the study, participants were asked to report which strategies were most effective for reducing sedentary time. All participants (19/19) reported that the pedometer was helpful, but participants who averaged <5000 steps per day at baseline found the 7500 goal to be too high. Future research should consider setting more modest incremental step goals based on the participant's baseline level of steps. While the intervention targeted sedentary time, participants reported that the step goal was helpful, because it provided instant quantitative self-monitoring feedback. Based on these findings, a device that tracks and provides instant quantitative feedback specific to sedentary time may help participants reduce sedentary time. Approximately half (10/19) of the participants found the hourly checklist (where they reported whether they had stood for five or more minutes each hour) to be helpful, and they reported completing it as they finished activities. The remaining nine only completed the hourly checklist either daily or every few days. These simple strategies, targeting small behavioral changes and providing self-monitoring tools, may be useful for future interventions targeting reductions in sedentary time.

4.3. Sensitivity of Measurement Tools. The AP was used as the criterion to differentiate responders to the intervention from nonresponders [23]. In this study, we confirmed the AP was sensitive to the reductions in sedentary time, but the AG and the self-report questionnaires were not. A novel aspect of this study was that it examined the sensitivity and specificity of the various measures for detecting changes in behavior. In intervention studies, it is important to use measures with high sensitivity and specificity to insure that changes can be detected and to minimize sample size requirements. Sensitivity reflects the ability of a measure to correctly classify true behavior change. For example, the sensitivity of the AG100 was 67% for weekend days. That is, one-third of subjects who actually changed their behavior according to the AP were not classified as changing their behavior according to the AG100. The specificity was lowest for the D-SQ and T-SQ, indicating that participants were more likely to report they changed behavior when they were actually nonresponders to the intervention (according to the AP). In addition, the misclassifications across measures were not occurring for the same individuals. For example, five individuals were misclassified according to the D-SQ, T-SQ, and AG150 for weekend days, but it was not the same five individuals for each measure (see Table 3).

The results comparing sensitivity to change of the AG and AP are consistent with our previous results which used 6 hours of direct observation as the criterion measure [23]. Gardiner and colleagues previously reported the AG was modestly sensitive to change and detected a significant decrease in sedentary time (3.2%) using the AG100 [31]. Their study included 48 individuals, which suggests that the AG may be able to detect change in a larger sample. However, in the current study, eight minutes *more* sitting

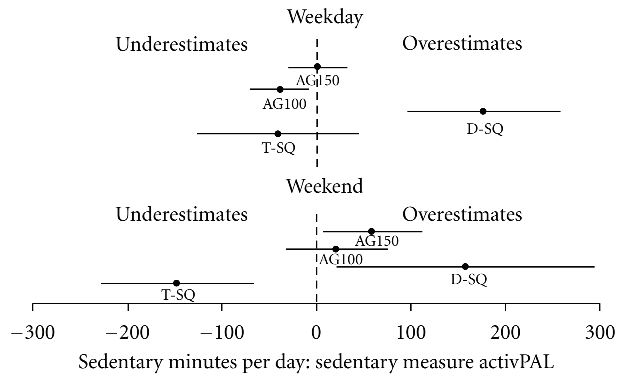

Figure 1: Illustration of the under- and overestimation of sedentary time for each measure compared to the activPAL monitor for (a) weekend (b) weekdays. The closed circles are the bias and the lines illustrate the 95% confidence intervals. AG100 refers to the ActiGraph cut-point of 100 counts$\cdot$min^{-1}, AG150 refers to the ActiGraph cut-point of 150 counts$\cdot$min^{-1}, T-SQ is a single-item total sedentary time questionnaire, and D-SQ is a 5-domain sedentary time questionnaire. Data includes 13 participants with valid data for all measures during both the baseline and intervention period.

time on weekend days was recorded with the AG measures in the intervention period compared to the baseline period. In contrast, the AP recorded 54 minutes *less* sitting on weekend days in the intervention period. Participants spent more time standing on weekends (31% of AP wear time) than on weekdays (23.4% of wear time) in the intervention period. This suggests that the AG does not distinguish standing from sitting. This is not surprising, since the AG device is not designed to differentiate postures. If a person is standing still or standing with small amounts of movement, this will be interpreted as sedentary time using the AG cut-point method. This will cause measurement problems for interventions, where participants are encouraged to replace sitting with standing.

4.4. Convergent Validity of AG. The AG100 cut-point was more accurate than the AG150, and that differs from our previous work which used the same subjects and direct observation as the criterion measure (Figure 1). In the current study, there were differences in the accuracy of the cut-points depending on how much the participant was sedentary. When sedentary time was highest (on weekdays ~67%), the AG150 was not different from the AP, while the AG100 significantly underestimated sedentary time. When sedentary time was lower (on weekend days ~62.7%), the AG150 significantly overestimated sedentary time, while the AG100 was not significantly different from the AP. In our previous study, participants were directly observed while at work over a 6-hour period, and the percent of time sedentary according to the AP was considerably higher for both the baseline period (79.5%) and intervention period (66.5%) than the current study, which may explain the discrepancy. Additionally, it should be noted that following an intervention designed to increase standing and decrease sedentary time, the AG150 may misclassify standing as sedentary behavior and inflate sedentary time. In a highly sedentary population, the AG100 may underestimate sedentary time.

Accuracy using the AG100 and AG150 was slightly different, and both were equally precise with the 95% confidence intervals of about 50 minutes. While the accuracy of a given cut-point may change depending on the level of sedentary behavior, the precision will not. Lower precision increases sample size requirements for intervention trials. It is also important to note that the AG monitors did detect significant differences pre- to postintervention for minutes in MVPA, which increased significantly during the intervention period from 16.1 min to 24.6 min ($P < 0.01$). To date, limited work has been done validating MVPA estimates from the AP. Therefore, intervention studies targeting both sedentary time and MVPA should consider using the AG.

4.5. Convergent Validity of Questionnaires. To our knowledge, this is the first study comparing questionnaire estimates of sedentary time to the AP. In contrast to the T-SQ, which underestimated sedentary time, the D-SQ overestimated sedentary time. Therefore, it is very important to consider the type of questionnaire when attempting to compare prevalence estimates across populations. Clemes et al. compared two sedentary behavior questionnaires to the AG100 [32]. Similar to our results, they reported the single-item T-SQ underestimated sedentary time by over two hours on weekend days. In the current study, the difference between the T-SQ and the AP was not significant on weekdays, while Clemes et al. did report a significant underestimation of sedentary time [32]. They reported no significant difference for the D-SQ compared to the AG100, which is different than what we reported when comparing the questionnaires to the AP. While participants were instructed to avoid double-reporting of time in multiple domains, it is possible that this occurred. Another explanation is that participants were awake for more time than they wore the monitors, which leaves potential time for participants to be sedentary that is not captured by the monitors. In the Clemes et al. [32] study, participants reported in a diary how much they sat each day during the week, which may have improved their awareness of sedentary time. Further, while the average difference in their study was small, they reported very wide limits of agreement using a Bland-Altman analyses (weekday = −382.0 to 354.6 min; weekend day = −578.5 to 570.2 min) which is consistent with the large individual differences in the present study. Only considering one domain (TV viewing) was not sufficient to detect change in behavior and was not correlated with overall sedentary time. While the evidence linking high levels of TV viewing to poor health outcomes is robust, a more comprehensive measure of sedentary time should be used by future studies that examine the dose-response relationships of overall sedentary time and health.

This study has important limitations that should be noted. We used a ten hour cutoff to define a valid day using the activity monitors. This is considered best practice for accelerometer studies and previous validation studies of sedentary questionnaires [20], but the 10-hour criterion was originally designed for studies that primarily measure

MVPA [28]. Future work should examine if this is a valid criterion for determining minimum wear time needed in sedentary behavior studies. Future research, using a larger sample size, should examine the difference in estimates of sedentary time using different daily wear time criteria. The second limitation is that the sample was small and homogenous, but it is worth pointing out that subjects in this study are probably similar to those who will be targeted for future intervention (overweight/obese, nonexercising, and sedentary occupations). It is important to note that the results can only be generalized to a similar population of highly sedentary, overweight, and nonexercising office workers. Finally, this study demonstrates that short-term, free-living sedentary time reductions are possible. However, while the change we observed was statistically significant, a ~5% (48 minute) reduction in sedentary time per day may not be sufficient to elicit health benefits even if sustained for a longer duration. Future research is needed to explore the health benefits of longer-term reductions in sedentary time.

The strengths of this study are the within subject design that allowed us to explore key measurement limitations in the literature in unique ways. Particularly, the sensitivity to change analyses using sensitivity and specificity will inform researchers of sample size requirements for future intervention trials. In the current study, we used the AP as a criterion for changes in behavior and for measuring sedentary time. The AP has been shown to correctly classify free-living sedentary time over 97.2% of the time [23, 24]. While this is not 100% accurate, we believe the effects on the comparisons across measures are small though they may exist. To date, few studies have used the AP monitor, or a comparably accurate criterion measure, to assess the efficacy of interventions or to examine the convergent validity of sedentary time measures. In addition, our study is the first known sedentary behavior intervention study in adults to use the AP as the primary outcome measure. Finally, we provide a number of strategies and behavior change tools for future interventions that target reductions in sedentary time.

In conclusion, this study confirmed that the AP monitor is sensitive to change, and the AG monitor and self-report questionnaires are less sensitive. We provide data that improves our understanding of the measurement properties of devices and self-report tools. These data will help inform sample size estimates for future interventions. The AG100 was more accurate when sedentary time was lower, while the AG150 was more accurate when sedentary time was higher. This discrepancy highlights the inherent limitations of estimating sedentary time using a simple cut-point from a waist-mounted accelerometer. When possible, researchers should use a device that is specifically designed to measure posture for intervention studies that target sedentary time. In addition, we showed that a ~50 minute per day reduction in sedentary time is possible using targeted messages to replace sedentary time with standing and light-intensity activity. While there is evidence linking sedentary behavior to health, there remains a paucity of controlled trials examining the effect of reducing sitting time on health outcomes [25]. In the future, long-term randomized controlled trial studies are necessary to demonstrate the effect of reducing sedentary time on the cardiometabolic risk factors associated with chronic diseases.

Disclosure

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Research Article

Unraveling the Relationship between Smoking and Weight: The Role of Sedentary Behavior

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Research has shown that current smokers have a lower mean body mass index (BMI) than never and former smokers, with former smokers having the highest mean BMI. A number of physiological mechanisms have been hypothesized to explain this pattern, but few studies have explored the possible role of behavioral factors. Using data from the cross-sectional National Health and Nutrition Examination Survey 1999–2006, this descriptive study explored the associations among smoking status, sedentary behavior, and two anthropometric measures (BMI and waist circumference (WC)). Sedentary behavior was significantly higher among current smokers compared to never and former smokers; former smokers had higher levels of sedentary behavior compared to never smokers. The association between smoking status and anthropometric outcomes was moderated by sedentary behavior, with current smokers evidencing higher BMI and WC at higher levels of sedentary behavior compared to lower levels of sedentary behavior. Results are discussed in terms of their implications for interventions, particularly with respect to postcessation weight gain.

1. Background

Obesity and tobacco use are the two leading causes of preventable death and disease in the United States [1]. Despite declines in smoking prevalence from a peak in the 1960s, tobacco use remains the leading cause of preventable death and disease in the USA [2]. It is estimated that 440,000 Americans die prematurely each year as a result of tobacco use and exposure [3]. Approximately 20.6% of USA adults are current smokers, defined as smoking at least 100 cigarettes during their lifetime and every day or some days currently [4]. As smoking rates have declined, obesity rates (having a body mass index (BMI) of 30 or higher) have doubled in the USA since 1980 with recent data indicating that more than 33% of USA adults are obese [5]. The rate of mortality due to overweight/obesity is estimated to account for approximately 365,000 deaths yearly [6].

Research indicates that smoking and body weight are interrelated, but the relationship is complex and not well understood. In general, cigarette smoking has an inverse association with body weight or BMI [7–9], and smoking cessation has been linked to weight gain [8, 10, 11]. Few studies have examined the relationship between smoking and body shape, specifically central adiposity. Some studies suggest that smokers have greater abdominal obesity compared to nonsmokers [12–14]. Independent of overall adiposity, having a larger waist circumference (WC), or android body shape, is associated with mortality in adults age 50 and older and metabolic disease risk [15–17]. Body shape, rather than BMI, may better explain why smokers have a higher risk of metabolic syndrome, in particular type 2 diabetes [18]. A number of biological mechanisms have been proposed to explain this relationship between smoking and body weight including nicotine's effect on metabolism and its role as an appetite suppressor [19, 20]. Additional hypothesized mechanisms include nicotine's impact on glucose tolerance and insulin sensitivity and its role in increased lipoprotein lipase activity [21]. However, despite the clear pharmacological effects of nicotine, it may be that behavioral factors also play an important role in the relationship between smoking status and weight, particularly in the context of smoking cessation. People who smoke may be more likely to be physically inactive or engage in other poor health habits. Furthermore, the physiological effects of nicotine may mask the deleterious effects of poor diet and physical inactivity for weight.

Smoking has often been described as a "gateway behavior" as people who start smoking are likely to engage in other health risk behaviors (e.g., use of other drugs, excessive use of alcohol), and a growing body of research suggests that people who engage in one health risk behavior (e.g., smoking) are likely to engage in others (e.g., poor diet) [22–24]. However, as noted above, the links between smoking and weight are somewhat complicated and less well understood—varying as a function of smoking status (e.g., current versus former smokers) and the metabolic benefits that nicotine conveys. A better understanding of the interplay between smoking and weight may be derived from focusing on the associations between smoking status and the behaviors linked to BMI including diet, physical activity, and sedentary behaviors. To these authors' knowledge, little previous epidemiological and descriptive work has examined the associations between smoking status and weight-related behaviors. It is possible that negative weight-related health behaviors established while a person is a current smoker are masked by some of the physiological metabolic benefits of smoking. These metabolic benefits may be less pronounced at extreme levels of some weight-related health behaviors (e.g., having 4 or more hours of sedentary leisure time per day).

Understanding how these weight-related health behaviors are associated with smoking status is important for understanding the cumulative health risk that current smokers may have as a function of the multitude of risk behaviors in which they engage [25]. Further, understanding patterns of weight-related behaviors that are characteristic of current smokers may serve to inform interventions that target postcessation weight gain. To date, interventions that include weight management in the context of smoking cessation treatment have targeted increasing physical activity, decreasing calorie intake, or both [26–30]. However, a meta-analysis examining weight-related behavioral interventions to reduce postcessation weight gain concluded that combined smoking cessation and weight control treatments result in significantly higher short-term smoking abstinence rates compared to smoking treatments alone, with no statistically significant weight maintenance benefit long term (>6 months) [31]. As described, these interventions focused primarily on reducing caloric intake or increasing physical activity. None have focused on the role of sedentary behavior, which has been shown to be an independent risk factor for obesity and related health outcomes [32, 33]. Thus, more research is needed to better understand the emergence of weight-related health behaviors in the context of current smoking. Addressing sedentary behavior may be particularly important in this population in terms of its contribution to risk for disease in current smokers and to inform future interventions targeting weight management among those who are trying to stop smoking.

Sedentary behavior is defined as any activity that does not increase energy expenditure substantially above a resting level including behaviors such as sleeping, sitting, and lying down [34]. Sedentary behavior is often assessed as leisure "screen time" such as watching TV, watching videos, or using a computer. While this is a new area for empirical research, existing studies have used self-reported sitting time as a marker of sedentary behavior [35–37]. Research has shown that the test-retest reliability for TV viewing and computer use is excellent among older adults, suggesting that in the absence of objective sedentary measurement, self-reported measures may be used as an alternative [36].

It is important to note that sedentary behavior is not synonymous with physical inactivity [37, 38]. An individual can meet guidelines for high physical activity and also have long periods of sedentary behavior during the day. Research to date has suggested that sedentary behavior (independent of time spent sleeping) is a risk factor for overweight/obesity and other health outcomes, distinct from the health benefits of physical activity [33, 39–41]. Of substantial concern, sedentary behavior appears to be widespread within the USA population. Accelerometer data from USA individuals age six and older revealed that individuals spend almost 55% of their monitored time (10-hour day) in sedentary behaviors [42]. A 2007 study offered further support for high levels of sedentary behavior within the USA adult population such that adults spent more than half (9.3 hours/day) of their waking hours in sedentary activities and the remainder in light intensity physical activity (6.4 hours/day) with less than one hour a day in moderate to vigorous physical activity [43]. Although research has indicated that current smokers are less likely to be physically active than their nonsmoking counterparts, little is understood about the interplay between smoking status and sedentary behavior [44, 45].

The primary objective of this descriptive study is to better understand the relationships among sedentary behavior, smoking status, and body weight/shape in the USA population. This study used cross-sectional population level data to describe sedentary behavior patterns including characteristics associated with sedentary behavior. We have chosen to focus our analysis on sedentary behavior, and not physical activity, given the significant findings in the literature of sedentary behavior as an independent risk factor for chronic disease and a shift in public health to target interventions on decreasing sedentary behavior [32–34, 37, 46]. We tested the relationship between smoking status and sedentary behavior and the unique contributions of each of these factors to two anthropometric outcomes, BMI and WC. The final objective of this study was to test whether the relationship between sedentary behavior and anthropometric measures (BMI and WC) varied as a function of smoking status.

2. Materials and Methods

2.1. Data Collection. The current study utilized the National Health and Nutrition Examination Survey (NHANES) continuous data from 1999 to 2006 to test the associations among Smoking status and sedentary behavior were assessed via anthropometrics (i.e., BMI and WC). The NHANES uses a complex, multistage, probability-sampling design to obtain a nationally representative sample of the USA population. Beginning in 1999, continuous NHANES datasets have been released every two years. Data for the current study came from two primary sources: a direct interview and physical examination. Smoking status and sedentary behavior were assessed via self-report within the interview portion of the survey. Body measurements were taken by trained health technicians in NHANES mobile examination centers (MECs) using standardized examination methods and calibrated equipment.

2.2. Measures

Body Mass Index (BMI). BMI was computed from weight and standing height from the physical examination. The following formula was used: BMI = Weight (kg)/Height (m^2). Participants were categorized using the CDC cutoff points for adult obesity (BMI $\geq$ 30.0) versus not obese (BMI $<$ 30).

Waist Circumference (WC). WC was measured in centimeters in the physical examination and used as a continuous variable within these analyses as no clear clinical guidelines for cut points exist. Examiners located the right ilium of the pelvis, drew a horizontal line just above the uppermost lateral border, and used a tape measure, keeping it horizontal, around this point.

Sedentary Behavior. A survey item asked participants about their typical daily hours of sedentary behavior outside of work over the past 30 days. This measure assessed hours spent sitting and watching TV or videos; the item used in the 1999–2002 survey years also included computer use. Low sedentary behavior was defined as reporting one hour or less per day, moderate sedentary behavior was defined as two to three hours, and high sedentary behavior was defined as four or more hours of reported sedentary behavior. Prior studies have used this measure of sedentary behavior and similar categories [32, 35–37, 47].

Smoking Status. All participants were asked "Have you ever smoked 100 cigarettes in your entire life?" Never smokers were those who answered "no" to this question. Individuals who answered yes to this question were further asked, "Do you now smoke cigarettes?" Those who answered "yes" were classified as current smokers. Former smokers were those who answered "no" to this question.

Covariates. Sociodemographic characteristics including sex, age, ethnicity, and education were collected. Participants reported on average how many times per week they eat meals that were prepared in a restaurant or not at home (never or less than weekly, one time per week, or multiple times per week). Prior studies have used out of home eating and have shown that it is positively associated with greater weight [48–50]. Survey year was also included as a categorical variable clustered by two-year increments. This was included as overweight and obesity rates have increased significantly over the survey period.

2.3. Data Analyses. SAS callable Sudaan was used to estimate standard errors of point estimates for the complex survey data. All data were weighted to provide representative estimates of the USA adult population. Pregnant women and those under 20 years of age were excluded from analyses. Chi-square analyses and t-tests were used to examine the bivariate associations between sedentary behavior, smoking, weight variables, and covariates. Logistic regression was used to examine the influence of sedentary behavior and smoking on obesity (BMI $\geq$ 30, versus not obese) controlling for sex, age, education, race, survey year, and dining out. Linear regression analysis was used to examine the effect of sedentary behavior and smoking status on WC controlling for sex, age, education, race, survey year, and dining out. Moderation was examined by including interaction terms for sedentary behavior by smoking status in these models to determine if sedentary behavior's effect on weight outcomes differed by smoking status.

3. Results

Descriptive statistics for sedentary behavior are reported in Table 1. Over 20% of the population reported four or more hours of leisure time sedentary behavior per day over the last 30 days. BMI and sedentary behavior were significantly related such that those with less sedentary behavior had a significantly lower BMI ($F(2) = 100.44$, $P < .0001$). WC and sedentary behavior were significantly related such that those with less sedentary behavior had a significantly smaller WC ($F = 173.30$, $P < .0001$). Almost 30% of current smokers reported high sedentary behavior compared to only about 20% of never smokers. Sedentary behavior was lower in never smokers compared to former smokers ($t = -8.88$, $P < .0001$); and lower in former smokers compared to current smokers ($t = -3.89$, $P = .0003$). Thus, current smokers evidenced the highest levels of sedentary behavior.

Mean BMI for all smoking status categories fell within the overweight category (25.0 $\geq$ BMI $\leq$ 30.0). BMI was greater in former smokers (M = 28.81, SE = .15) compared to never smokers (M = 28.40, SE = .33; $t = -2.85$, $P = .0060$) and greater in never smokers compared to current smokers (M = 27.18, SE = .12; $t = 7.82$, $P < .0001$). Similarly, WC was greater in former smokers (M = 99.95, SE = .37) compared to never smokers (M = 95.92, SE = .33; $t = -10.83$, $P < .0001$) and greater in never smokers compared to current smokers (M = 94.86, SE = .32; $t = 2.59$, $P = .0121$). Thus, current smokers had the lowest BMI and WC, whereas former smokers had the highest.

Table 1: Descriptive statistics for sedentary behavior.

Weighted % (unweighted N)	Sedentary behavior			
	Low (≤1 hour)	Moderate (2-3 hours)	High (≥4 hours)	Total (row)
Total	31.42 (5172)	45.39 (7873)	23.19 (4594)	100 (17639)
Smoking status				
Never	35.79 (2962)	44.85 (3984)	19.35 (1958)	49.94 (8904)
Former	28.65 (1214)	46.64 (2190)	24.71 (1320)	25.27 (4724)
Current	25.44 (988)	45.29 (1691)	29.27 (1308)	24.78 (3987)
		Chi2 = 48.42, df = 4, $P < .0001$		
BMI				
Not obese	34.03 (3790)	45.20 (5404)	20.77 (2858)	69.07 (12065)
Obese	25.58 (1382)	45.82 (2469)	28.60 (1736)	30.93 (5592)
		Chi2 = 73.47, df = 2, $P < .0001$		
Waist circumference				
Smaller	35.56 (2919)	45.15 (3970)	19.28 (2007)	52.04 (8905)
Larger	26.92 (2253)	45.65 (3903)	27.43 (2587)	47.96 (8752)
		Chi2 = 85.16, df = 2, $P < .0001$		
Sex				
Male	29.53 (2520)	47.46 (4148)	23.01 (2346)	49.52 (9019)
Female	33.27 (2652)	43.35 (3725)	23.37 (2248)	50.48 (8638)
		Chi2 = 13.08, df = 2, $P < .0001$		
Race				
White	31.58 (2550)	46.28 (4074)	22.14 (2244)	71.95 (8879)
Black	24.26 (839)	39.60 (1433)	36.14 (1349)	10.87 (3624)
Mexican American	36.29 (1338)	47.21 (1773)	16.50 (692)	7.28 (3805)
Other	34.50 (445)	43.96 (593)	21.54 (309)	9.89 (1349)
		Chi2 = 33.06, df = 6, $P < .0001$		
Age (years)				
20–40	34.99 (2027)	44.43 (2637)	20.59 (1314)	39.80 (5979)
41–60	34.50 (1849)	45.65 (2487)	19.85 (1228)	38.16 (5566)
61+	19.62 (1296)	46.67 (2749)	33.70 (2052)	22.05 (6112)
		Chi2 = 49.14, df = 4, $P < .0001$		
Education				
< HS	26.80 (1601)	42.50 (2358)	30.69 (1651)	20.00 (5619)
HS	26.19 (1053)	45.62 (1871)	28.19 (1290)	25.96 (4216)
Associates or some college	31.63 (1310)	46.01 (2132)	22.35 (1132)	29.86 (4578)
≥ College	40.57 (1196)	46.83 (1498)	12.59 (511)	24.18 (3206)
		Chi2 = 43.96, df = 6, $P < .0001$		
Survey year				
1999-2000	27.73 (1179)	47.91 (1893)	24.36 (1045)	22.65 (4121)
2001-2002	30.38 (1291)	44.02 (2060)	25.60 (1301)	26.05 (4661)
2003-2004	33.59 (1340)	44.35 (1968)	22.07 (1167)	25.39 (4475)
2005-2006	33.57 (1362)	45.58 (1952)	20.86 (1081)	25.90 (4400)
		Chi2 = 5.65, df = 6, $P = .0001$		
Dining out (per week)				
<1 time or never	30.05 (1443)	40.17 (2018)	29.78 (1561)	21.84 (5031)
1 time	33.22 (1151)	44.91 (1730)	21.87 (907)	20.53 (3790)
≥2 times	31.30 (2578)	47.53 (4125)	21.17 (2126)	57.63 (8835)
		Chi2 = 25.51, df = 4, $P < .0001$		

Table 2: Logistic regression analyses predicting obesity (BMI).

	Odds ratio (confidence interval)	Beta (confidence interval)	P value
Sedentary behavior			
Low (≤1 hour)	1.00	0	—
Moderate (2-3 hours)	1.34 (1.22–1.48)	0.30 (.20–.39)	<.0001
High (≥4 hours)	1.78 (1.59–2.01)	0.58 (.46–.70)	<.0001
Smoking status			
Never	1.00	0	—
Former	1.06 (0.96–1.18)	0.06 (−.05–.16)	.2659
Current	0.69 (0.61–0.77)	−.38 (−.49– −.26)	<.0001
Dining out (per week)			
<1 time or never	1.00	0	—
1 time	1.11 (0.97–1.27)	0.10 (−.03–.24)	.1284
≥2 times	1.32 (1.19–1.47)	0.28 (.18–.38)	<.0001
Sex			
Male	1.00	0	—
Female	1.23 (1.14–1.34)	0.21 (.13–.29)	<.0001
Race			
Non-Hispanic white	1.00	0	—
Non-Hispanic black	1.52 (1.40–1.65)	0.42 (.34–.50)	<.0001
Mexican American	1.10 (0.96–1.27)	0.10 (−.04–.24)	.1752
Other	0.80 (0.68–0.94)	−0.22 (−.38– −.06)	.0071
Age	—	0	.3139
Education			
< HS	1.44 (1.23–1.69)	0.37 (.20–.53)	<.0001
HS	1.54 (1.34–1.77)	0.43 (.30–.57)	<.0001
Associates/some college	1.43 (1.26–1.63)	0.36 (.23–.49)	<.0001
≥ College	1.00	0	—
Survey year			
1999-2000	1.00	0	—
2001-2002	0.95 (0.80–1.13)	−0.05 (−.23–.12)	.5389
2003-2004	1.11 (0.94–1.31)	0.10 (−.06–.27)	.2022
2005-2006	1.20 (1.00–1.45)	0.19 (−.00–.37)	.0512

Results from a logistic regression analysis predicting obesity are presented in Table 2. Compared to individuals with low levels of sedentary behavior (≤1 hour/day), those reporting moderate sedentary behavior were 1.34 times more likely to be obese, and those with high sedentary behavior levels were 1.78 times more likely to be obese. The probability of current smokers being obese was 0.69 times that of never smokers. Individuals who reported dining out two or more times per week were 1.32 times more likely to be obese compared to those who dined out less than one time a week. Participants who were male, in the "other" race category, and had greater education had a lower likelihood of being obese. There was no statistically significant influence of survey year; however, a trend for greater obesity in more recent years was noted.

Results from a linear regression analysis predicting WC are presented in Table 3. Compared to individuals with low levels of sedentary behavior (≤1 hour/day), those with moderate sedentary behavior had a WC 2.24 cm larger ($P < .0001$), and those with high sedentary behavior had a WC 5.52 cm larger ($P < .0001$) controlling for all other variables in the model. Current smokers had a 2.42 cm smaller WC compared to never smokers ($P < .0001$), whereas former smokers had a 1.06 cm larger WC ($P = .0042$). Similar to BMI, in the multivariate model, those in the "other" race category and having higher education had lower odds of a larger WC. However, females were less likely to have a larger WC than males. Greater age was associated with a larger WC. The two most recent survey years showed a statistically significantly higher WC compared to the first survey year.

To test the moderating role of smoking status in the association between sedentary behavior and weight outcomes, an interaction term was included in each of the two models reported above (see Table 4). The results from the logistic regression analysis predicting obesity showed that smoking status moderated the relationship between sedentary behavior and BMI ($F(4) = 4.13, P = .0051$). In the adjusted model, low sedentary former and moderate and high sedentary never and former had significant increased odds of obesity compared to low sedentary never smokers. Highly sedentary

Table 3: Linear regression analyses predicting waist circumference.

	Beta coefficient (confidence interval)	P value
Sedentary behavior		
Low (≤1 hour)	0	—
Moderate (2-3 hours)	2.24 (1.60–2.88)	<.0001
High (≥4 hours)	5.52 (4.66–6.39)	<.0001
Smoking status		
Never	0	—
Former	1.06 (.35–1.78)	.0042
Current	−2.42 (−3.19– −1.64)	<.0001
Dining out (per week)		
<1 time or never	0	—
1 time	0.94 (.06–1.82)	.0365
≥2 times	2.05 (1.40–2.69)	<.0001
Sex		
Male	0	—
Female	−6.80 (−7.41– −6.18)	<.0001
Race		
Non-Hispanic white	0	—
Non-Hispanic black	0.83 (.10–1.56)	.0257
Mexican American	−0.11 (−1.14–.92)	.8355
Other	−2.46 (−3.72– −1.21)	.0002
Age	0.17 (.16–.19)	<.0001
Education		
< HS	2.95 (1.99–3.92)	<.0001
HS	3.25 (2.42–4.08)	<.0001
Associates/some college	2.80 (2.03–3.57)	<.0001
≥College	0	—
Survey year		
1999-2000	0	—
2001-2002	0.55 (−.69–1.80)	.3771
2003-2004	1.94 (.68–3.21)	.0031
2005-2006	2.08 (.54–3.62)	.0090

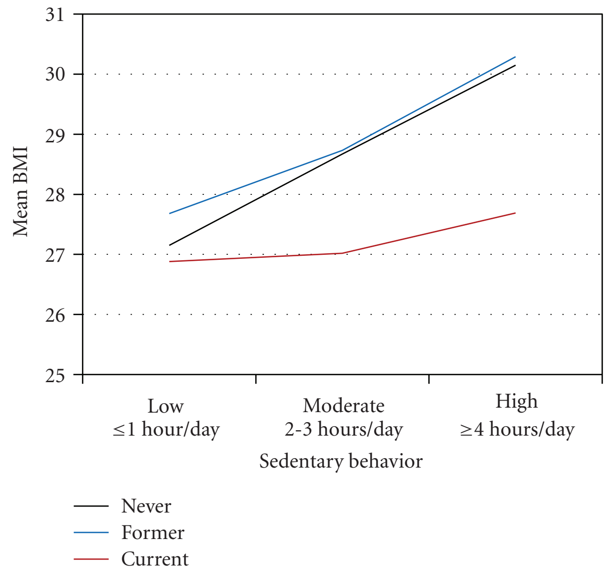

Figure 1: The interactive effect of SB and smoking status on obesity.

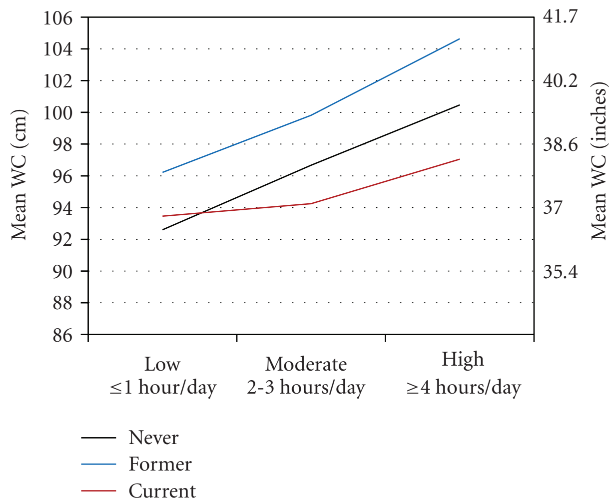

Figure 2: The interactive effect of SB and smoking status on WC.

current smokers were at marginally increased odds of obesity compared to low sedentary never smokers ($P = .0876$). Figure 1 shows mean BMI as a function of smoking status at varying levels of sedentary behavior. As shown, there were no statistically significant differences in mean BMI between never and former smokers as a function of sedentary behavior. However, there were statistically significant differences in mean BMI between never and current smokers as a function of sedentary behaviors. As shown in Figure 1, at moderate and high levels of sedentary behavior, mean BMI differed between never and current smokers such that current smokers had lower BMI ($t = 1.97$, $P < .0001$; $t = 8.16$, $P < .0001$, resp.; Cohen's $d = 11.97$, $r = .99$). Those with the highest levels of sedentary behavior in all smoking status categories had the highest mean BMI. Further, it is worth noting that, as shown in Figure 1, although BMI was relatively similar for current smokers at low and moderate levels of sedentary behavior, BMI was notably higher for smokers at high levels of sedentary behavior.

The results from the linear regression (see Table 5) analysis predicting WC demonstrated that smoking status also moderated the association between sedentary behavior and WC ($F(4) = 4.73$, $P = .0022$). In the adjusted model, low sedentary former smokers, moderately sedentary never and former smokers, and highly sedentary never, former, and current smokers had significantly larger WC compared to low sedentary never smokers. Figure 2 shows the WC means as a function of smoking status at varying levels of sedentary behavior. As shown, at low levels of sedentary behavior, current smokers had a slightly larger WC than never smokers although this difference was not statistically significant ($t = -1.48$, $P = .1455$). Former smokers had a significantly larger WC compared to current smokers ($t = -3.89$, $P = .0003$) at low levels of sedentary behavior. As was the case with BMI,

Table 4: Analyses predicting body mass index (BMI) including interaction terms.

	Odds ratio (confidence interval)	Beta coefficient (confidence interval)	P value
Low sedentary never smoker	1.00	—	—
Low sedentary former smoker	1.19 (1.00–1.41)	0.17 (.00–.34)	.0490
Low sedentary current smoker	.93 (0.77–1.13)	−0.07 (−.26–.12)	.4642
Moderate sedentary never smoker	1.52 (1.34–1.74)	0.42 (.29–.55)	<.0001
Moderate sedentary former smoker	1.46 (1.26–1.70)	0.38 (.23–.53)	<.0001
Moderate sedentary current smoker	.98 (0.85–1.14)	−.02 (−.17–.13)	.8312
High sedentary never smoker	2.01 (1.72–2.36)	0.70 (.54–.86)	<.0001
High sedentary former smoker	2.23 (1.86–2.67)	0.80 (.62–.98)	<.0001
High sedentary current smoker	1.18 (0.98–1.42)	0.16 (−.02–.35)	.0876
Dining out (per week)			
<1 time or Never	1.00	0	—
1 time	1.11 (0.97–1.27)	0.10 (−.03–.24)	.1368
≥2 times	1.32 (1.19–1.46)	0.28 (.17–.38)	<.0001
Sex			
Male	1.00	0	—
Female	1.24 (1.14–1.34)	0.21 (.13–.29)	<.0001
Race			**<.0001**
Non-Hispanic white	1.00	0	—
Non-Hispanic black	1.53 (1.40–1.66)	0.42 (.34–.51)	<.0001
Mexican American	1.10 (0.96–1.27)	0.10 (−.05–.24)	.1782
Other	0.80 (0.68–0.94)	−0.22 (−.38– −.06)	.0073
Age	1.00	0	.3633
Education			
< HS	1.43 (1.22–1.69)	0.36 (.20–.52)	<.0001
HS	1.53 (1.34–1.76)	0.43 (.29–.57)	<.0001
Associates or some college	1.42 (1.24–1.62)	0.35 (.22–.48)	<.0001
≥ College	1.00	0	—
Survey year			
1999-2000	1.00	0	—
2001-2002	0.95 (0.80–1.13)	−0.05 (−.23–.12)	.5442
2003-2004	1.11 (0.95–1.31)	0.11 (−.06–.27)	.1977
2005-2006	1.21 (1.00–1.46)	0.19 (.00–.38)	.0485

the most notable difference in WC among current smokers was at higher levels of sedentary behavior.

4. Discussion

These analyses from a nationally representative, cross-sectional dataset revealed several interesting findings regarding the interplay between smoking status, sedentary behavior, and indicators of weight status (i.e., BMI, WC). Smoking status and sedentary behavior were associated such that current smokers reported the highest levels of sedentary behavior, followed by former smokers and never smokers. Furthermore, this study revealed that smoking status moderated the relationship between sedentary behavior and weight-related outcomes in the USA population. In other words, at varying levels of smoking status, sedentary behavior had a different effect on BMI and WC. To the best of our knowledge, this is the first study to show the interactive effect of these modifiable risk behaviors that influence weight-related outcomes. In addition to using a measure of BMI, WC was also examined as an outcome variable. Importantly, although both BMI and WC were lower among current smokers compared to former and never smokers at almost all levels of sedentary behavior, the pattern of findings suggested that both BMI and WC were higher among current smokers at high levels of sedentary behavior. In addition, other factors associated with sedentary behavior including demographic characteristics and dining out were examined, highlighting important characteristics at the population level that will be critical to pursue in future research.

At low levels of sedentary behavior, current smokers and never smokers did not have significantly different BMI. However, at moderate and high levels of sedentary behavior, it appeared that current smokers had a significantly lower BMI compared to never smokers in those sedentary behavior categories. This is consistent with previous research.

Table 5: Analyses predicting waist circumference including interaction terms.

	Beta coefficient (confidence interval)	P value
Low sedentary never smoker	—	—
Low sedentary former smoker	1.30 (0.04–2.56)	.0432
Low sedentary current smoker	−0.47 (−1.52–0.59)	.3811
Moderate sedentary never smoker	2.88 (2.02–3.75)	<.0001
Moderate sedentary former smoker	3.58 (2.50–4.65)	<.0001
Moderate sedentary current smoker	0.07 (−.95–1.09)	.8910
High sedentary never smoker	6.35 (5.14–7.56)	<.0001
High sedentary former smoker	7.66 (6.27–9.05)	<.0001
High sedentary current smoker	2.55 (1.33–3.76)	<.0001
Dining out (per week)		
<1 time or never	0	—
1 time	.92 (.04–1.80)	.0403
≥2 times	2.01 (1.36–2.65)	<.0001
Sex		
Male	0	—
Female	−6.79 (−7.40–6.18)	<.0001
Race		
Non-Hispanic white	0	—
Non-Hispanic black	.82 (.11–1.54)	.0252
Mexican American	−.12 (−1.15–.91)	.8147
Other	−2.45 (−3.70–1.19)	.0002
Age	.17 (.15–.19)	<.0001
Education		
< HS	2.92 (1.96–3.88)	<.0001
HS	3.19 (2.37–4.01)	<.0001
Associates or some college	2.74 (1.97–3.50)	<.0001
≥ College	0	—
Survey year		
1999-2000	0	—
2001-2002	.57 (−.68–1.81)	.3656
2003-2004	1.94 (.69–3.20)	.0030
2005-2006	2.08 (.54–3.63)	.0091

Similarly, at low levels of sedentary behavior, smokers and never smokers did not have significantly different WC, yet again at moderate and high levels of sedentary behavior current smokers had a lower WC than never smokers. Prior research has demonstrated that nicotine has a number of physiological effects including increasing metabolism [19–21]. While the current study did not directly assess the impact of nicotine, it may be that there was a metabolic benefit of nicotine among current smokers at low and moderate levels of sedentary behavior as demonstrated on both the BMI and WC outcomes. That is, at low and moderate levels of sedentary behavior, nicotine may have buffered weight gain which would have occurred in current smokers and is demonstrated in former smokers.

Although current smokers were most sedentary, we also found that former smokers were more sedentary than never smokers. This suggests that a pattern of sedentary behavior may become established while people are current smokers. This pattern may continue after cessation for many former smokers. This has several important implications for both current and former smokers. First, it is possible that the physiological effects of nicotine mask the negative effects of sedentary behavior on weight status. However, when nicotine is removed during cessation, the impact of sedentary behavior on weight emerges in former smokers. Sedentary behavior may thus function as a potential mechanism of postcessation weight gain which could be directly targeted within an intervention.

Former smokers were also more likely to be obese and had a larger WC compared to never smokers in the bivariate analyses. When examining these weight differences in the context of sedentary behavior, never and former smokers had a similar BMI at varying levels of sedentary behavior. Conversely, never and former smokers had significantly different WC at all levels of sedentary behavior. These differences in body shape suggest that while former smokers may not be at risk for greater adiposity, they appear to be at risk for increased central adiposity compared to never smokers. Former smokers' higher risk for central adiposity may explain why this group is particularly at risk for weight-related health challenges (e.g., Type 2 diabetes). Both smoking cessation and sedentary behavior are associated with weight gain and metabolic syndrome [10, 51, 52]. Epidemiologic research has shown an association between sedentary behavior and chronic disease risk factors including central adiposity and elevated blood glucose and insulin [32, 53–56]. The results of the current study may help to explain recent findings that smokers who recently quit smoking were at increased risk of type 2 diabetes [52]. While we saw no difference between never and former smokers in terms of BMI in the model with the interaction term, we did see significant differences at varying levels of sedentary behavior between these two groups with regards to WC.

This research has important implications for smoking cessation interventions. The Clinical Practice Guideline for smoking cessation includes potential ways of addressing weight gain concerns when smokers make a quit attempt [57]. These include (1) explaining that the health risks of weight gain are small when compared to the risks of continued smoking, (2) recommending physical activities and healthy diet to control weight, and (3) suggesting that patients concentrate primarily on smoking cessation, not weight control, until ex-smokers are confident that they will not start smoking again [57]. The findings from the current study suggest that reducing time spent in sedentary behavior may be a potential intervention strategy and warrants further research. This may be a valuable and important public health message for the population as a whole, but in particular for smokers who are attempting to quit smoking.

The importance of these findings must be recognized in light of several limitations. The measurements of smoking status and sedentary behavior were self-reported. A study comparing self-reported smoking data to measurements of serum cotinine (a metabolite of nicotine) suggested that self-reported smoking was generally quite consistent with measured nicotine exposures [58]. It is likely that sedentary behavior was underreported and with a more refined self-report measure or objective sedentary behavior assessment, we may show stronger associations with smoking and weight-related outcomes. We attempted to include a measure of work-related sedentary behavior in follow-up analyses. However, limitations in the way this item was worded in the continuous NHANES survey (e.g., with a strong emphasis on lifting rather than general movement during work) led us to focus on leisure time sedentary behavior for this study. Importantly, we were able to see associations of this self-reported sedentary behavior with smoking and weight-related outcomes. Furthermore, leisure time sedentary behavior (rather than work place sedentary behavior) may be a more probable intervention point for public health practitioners. While we have proposed pathways for how these relationships may unfold, this data is cross-sectional in nature, and directionality must be tested in longitudinal studies. Future studies should also look specifically at how these risk factors and behaviors predict disease outcomes.

This study is the first nationally representative study to examine the relationships between sedentary behavior, smoking status, and weight-related outcomes. Our outcome measures, BMI and WC, were objectively assessed. Furthermore, the current study specifically examined the role of sedentary behavior, going beyond previous research that has focused on the links between smoking and physical activity [44, 45].

Future studies should examine more refined measures of smoking status, as prior studies suggest that there may be variation in weight outcomes depending on number of years smoking and amount smoked [59, 60]. Exploring sedentary behavior in the context of other factors that influence postcessation weight gain will be important for the development of weight management interventions in the context of smoking cessation. It will also be important to explore other co-occurring health behaviors including diet, physical activity, and alcohol consumption.

5. Conclusions

Both smoking and weight status have been identified as important public health concerns, contributing to a substantial percentage of preventable mortality in the USA. Over the past 20 years, a good deal of public policy has been devoted to reducing smoking in the general population. Obesity rates have soared over this same time period, and emerging evidence suggests that postcessation weight gain may be greater than previously thought, contributing to important health risks for former smokers such as diabetes, cardiovascular disease, and metabolic syndrome. Although it is likely that there are important physiological mechanisms involved in postcessation weight gain, behavioral factors may also be important contributors. The findings presented here speak to the role of sedentary behavior in the association between smoking status and weight status. Patterns of sedentary behavior may be established while people are current smokers. This has important implications for smoking cessation interventions which need to take into account both the potential health risks of postcessation weight gain and the psychological barrier that weight gain may pose to cessation efforts. Targeting sedentary behavior may be one mechanism through which these risks to cessation may be addressed.

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Research Article

Sitting Behaviors and Mental Health among Workers and Nonworkers: The Role of Weight Status

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Objective. To explore the associations between sitting time in various domains and mental health for workers and nonworkers and the role of weight status. *Design*. Cross-sectional analyses were performed for 1064 respondents (47% men, mean age 59 years) from the Doetinchem Cohort Study 2008-2009. Sedentary behavior was measured by self-reported time spent sitting during transport, leisure time, and at work. Mental health was assessed by the Mental Health Inventory (MHI-5). BMI was calculated based on measured body height and weight. *Results*. Neither sitting time during transport nor at work was associated with mental health. In the working population, sitting during leisure time, and particularly TV viewing, was associated with poorer mental health. BMI was an effect modifier in this association with significant positive associations for healthy-weight non-workers and obese workers. *Conclusion*. Both BMI and working status were effect modifiers in the relation between TV viewing and mental health. More longitudinal research is needed to confirm the results and to gain insight into the causality and the underlying mechanisms for the complex relationships among sedentary behaviors, BMI, working status, and mental health.

1. Introduction

In the past, advances in technology have caused a decrease in the time spent on physical activities and an increase in the time spent on sedentary behaviors [1]. For instance, viewing television (TV) and spending time on the computer keep both adults and children sedentary for many hours each day [2–5]. The etiology of obesity is complex and includes biologic, genetic, and behavioral contributors; however, the obesogenic environment that promotes a sedentary lifestyle plays an important role in the obesity epidemic [6, 7]. What is known about the health implications of sedentary behaviors, including weight outcomes and obesity, is summarized in several reviews. Based on cross-sectional studies, previous reviews concluded that there were generally positive associations between viewing TV and indicators of overweight [8, 9]. However, recent reviews of prospective studies are inconclusive, partly due to the poor methodological quality of the studies and conflicting results among the studies [10–12]. For other obesity-related health outcomes, that is, type 2 diabetes and mortality from all causes, and cardiovascular diseases (CVD), moderate to strong evidence was found for the longitudinal impact of sedentary behavior [11].

Although the research on sedentary behavior has been dominated by studies on its association with physical health, there is increasing research focusing on the association between sedentary behavior and mental health, especially depression [13–16]. A recent review showed positive associations between sedentary behaviors and the risk of depression among adults based on seven observational studies, while four intervention studies showed contradictory results [14]. In addition to depression, there are other common mental health measures, including anxiety and general mental health or mental well-being. However, the link between sedentary behavior and general mental health outcomes has received scant attention [17].

Among the Dutch population, there is a 14% yearly prevalence of self-reported poor mental health (defined by the Mental Health Inventory, MHI-5 ≤ 60) [18]. Considering the public health impact of poor mental health, insight into the association with sedentary behavior is relevant. Among adults, Hamer and colleagues (2010) found that recreational sedentary behavior by adults, defined by TV- and screen-based activity, was associated with poorer mental health scores [13].

Most studies on sedentary behaviors have focused on TV viewing. However, sedentary behaviors involve domains other than sitting during leisure, such as sitting at work or sitting during transport. Among working adults, who represent a major part of the adult population, a significant amount of time is spent at work, and the majority of their total sitting time each day is likely to be at work due to the organization of the work [2, 3].

With respect to the observed associations between TV viewing and mental health, several explanations can be proposed. In addition to possible physiologic mechanisms, there are possible behavioral explanations; for example, extended time spent viewing TV may lead to social isolation which adversely affects mental well-being [19]. Another possible explanation is the documented association between TV viewing and unhealthy (snack) food and beverage intake [20, 21]. With respect to the other side of energy balance, it has been hypothesized that TV viewing or other leisure-time sedentary behaviors may be substituted for beneficial physical activity that reduces the risk of depression [22]. Thus, TV viewing may be related to poorer mental health through reduced physical activity and obesity [20, 22–24]. It is yet unknown whether these associations also hold true for sedentary behaviors in other domains. For instance, for workers, is the relationship between sitting at work and mental health similar to TV viewing? Also, it is unknown whether the association between sedentary behavior and mental health is the same for workers and nonworkers. To date, evidence on these associations is lacking despite the relevance to reduce obesity and improve mental health.

Due to the current lack of knowledge on the relationship between various sedentary behaviors and mental health, the aim of this study was to explore the association between domain-specific sitting with mental health among workers and nonworkers. Weight status has shown to be associated with sedentary behaviors [8, 9], as well as with mental health problems [23, 25]; but the role of weight status in this association is yet unknown. Therefore, the second aim of the present study was to explore the role of weight status in the relationship between the various sedentary behaviors and mental health.

2. Methods

2.1. Participants. Data were derived from the Doetinchem Cohort Study, a Dutch, prospective, population-based study among residents from a town (Doetinchem) in the Netherlands. The data collection began among persons aged 20–59 years from 1987 to 1991 as part of the Monitoring Project on Cardiovascular Disease Risk Factors [26]. The cohort is reexamined every five years, and the fifth round (2008–2012) is ongoing. The measurements of the total study population are completed within a 5-year time frame, and each participant is measured every five years. Response rate was 62% in the first round, and varied between 75 and 79% in subsequent rounds. Starting with the fifth round, data have been collected about the time spent on sedentary behaviors. Since the data collection of the fifth wave is ongoing, only data from the first two years (2008 and 2009) are used in this study.

2.2. Procedure. The general aim of the Doetinchem Cohort Study is to study the impact of (changes in) lifestyle behaviors and biological risk factors on health outcomes during ageing [27]. Measurements were made via an extensive questionnaire and physical examination. All participants gave written informed consent and the study complied with Helsinki Declaration guidelines. Detailed information about sampling and data collection procedures has been described elsewhere [27].

2.3. Measures

2.3.1. Sedentary Behavior. Sedentary behavior was assessed by self-reported time spent sitting during a usual week over the past 12 months. The format of the sitting-time questions was similar to the questions about physical activity, which were designed for the European Investigation into Cancer and Nutrition (EPIC) [28]. The participants were asked to report their weekly sitting time (in hours) spent:

(1) traveling by motor vehicle (such as train, bus, car, tram, motorbike, motor) during
   - (a) commuting,
   - (b) work,
   - (c) leisure;

(2) sitting at work (behind desk, computer, or meeting);

(3) sitting during leisure time while
   - (a) reading and/or studying,
   - (b) TV viewing,
   - (c) sitting behind the computer,
   - (d) other sitting activities (talking with friends, playing games, listening to music, etc.).

From these items, three subscores were calculated by totaling the time spent sitting in each category: hours per week sitting during transport either for work or leisure time, hours per week sitting during work, and hours per week sitting during leisure time (either reading or studying, viewing television, computer time, or other sitting activities). Sitting time per domain was calculated only in those cases for which all underlying sitting activities were not missing. In all other cases, sitting time for the specific domain was considered as missing. Further, the time reported on each sitting activity was maximized at eight hours per day and seven days per week (five days/week for sitting at work) before calculating sitting time per domain. The total time spent sitting during the day was calculated by summing up the time spent sitting in the three domains, that is, transport, at work, and in leisure time. Again, total sitting time was calculated only in those cases for which all underlying domains of sitting were not missing. In all other cases, total sitting time was considered as missing.

2.3.2. Mental Health. Mental health was measured by the Mental Health Inventory (MHI-5), a subscale of the RAND 36 [29]. The MHI-5 is used to measure general mental health during the past month [17, 29] and has been found to be a valid and reliable measure of mental health status [29, 30]. The MHI-5 has five questions about feelings of depression and nervousness to be answered on a six-point scale ranging from "all of the time" [1] to "none of the time" [6]. The mental health score ranged from 0 to 100 points, calculated by first reversing the coding of the two positively formulated questions and consequently summing the points of each item $-5/25 * 100$, with a higher score reflecting better mental health. A dichotomous variable was created using a cutoff point of 60 [29, 31], indicating poor (≤ 60) versus good (>60) mental health.

2.3.3. Work Status. Using a single question, the respondents were asked whether they had paid work at the moment of the measurement. They could answer on a seven point scale with answers including "yes, as an employee (payroll)," "yes, self-employed," "no, I am housewife/man," "no, I am unemployed," "no, I am retired," "no, I am disabled," and "other". For the analyses, those working as an employee and self-employed were considered as a worker, while the remaining respondents, including "other," were treated as nonworkers.

2.3.4. Body Mass Index. Body weight and height were measured during a physical examination by trained assistants at the Municipal Health Services with participants wearing light indoor clothing, with emptied pockets and no shoes [27]. Body weight was assessed with a SECA balance scale to the nearest 100 g on a calibrated scale. Body height was measured with a stadiometer mounted to the wall while participants stood straight against a wall, with their feet at a 45-degree angle, to an accuracy of 0.5 cm. Both the SECA balance scale and the height stadiometer were calibrated each year. Body Mass Index was calculated by body weight in kilograms divided by body height in meters squared. Subsequently, BMI was categorized as healthy weight (BMI 18.5–24.9 kg/m^2), moderately overweight (BMI 25–29.9 kg/m^2), and obese (BMI $\geq$ 30 kg/m^2). Those participants who were underweight (BMI $<$ 18.5 kg/m^2) ($n = 3$) were excluded from the present analyses.

2.3.5. Covariates. Potential confounders of the association between sitting and mental health were assessed by means of self-administered questionnaires. Sociodemographic variables included gender, age (in years), and educational level. Educational level was assessed by the highest schooling achieved and was subsequently classified as low (intermediate secondary school or less), moderate (intermediate vocational or higher secondary education), or high (higher vocational education or university). Household composition was assessed by the question: "with which persons are you currently living together" using six answer categories: "not applicable," "I live alone," "with a partner," "with children up to 18 years of age," "with children 18 years or older," "with my parents" or "with other adults"). A dichotomous variable was created to distinguish participants living alone from participants living with others. Perceived general health was measured using a question from the RAND 36 [29, 30], which was dichotomized as "healthy" (including the answers "excellent," "very well," or "good") or "unhealthy" (including the answers "mediocre" or "bad"). Lifestyle behaviors included: physical activity, smoking, and alcohol consumption. Smoking status was defined as never, current, or former smoker. Data on alcohol consumption were categorized as 0 glasses/week, 1-2 (women) or 1–3 (men) glasses/week, or ≥ 2 (women) or ≥ 3 (men) glasses/week. An extended version of the physical activity questionnaire designed for the European Prospective Investigation into Cancer and Nutrition (EPIC) was used. This questionnaire included items on time spent on leisure-time activities (walking, bicycling, odd jobs, and gardening) during the summer and then during the winter [28]. For these activities, the lowest amount of time reported during either summer or winter was used in order to cautiously estimate physical activity levels. In addition, the questionnaire included items on sports and occupational activity irrespective of season. All reported sports were provided with a MET-value according to Ainsworth's updated compendium of physical activities [32]. Total time (hours/week) spent on moderately intense (4.0–6.5 METs) physical activity was calculated by taking the sum of the time reported on bicycling, gardening, sports (4.0–6.5 METs), and moderately intense activity at work (i.e., walking regularly while carrying heavy objects). Time (hours/week) spent on vigorous ($\geq$6.5 METs) physical activity was calculated by taking the sum of the time reported for sports ($\geq$6.5 METs). In addition, participants were categorized as either "adhering" ($\geq$3.5 hours/week of at least moderate physical activity) or "not adhering" to the physical activity guideline [33].

2.4. Statistics. Data were available for 1588 men and women, aged 41 to 80 years old, examined in 2008-2009. Participants with missing values for outcome variables and confounders were excluded from the analyses ($n = 521$). In addition, participants who were underweight ($n = 3$) were excluded, leaving 1064 men and women for the analyses.

Descriptive characteristics (mean and standard deviation or percentage) for all key variables were calculated for the study population as a whole and stratified by working status. The association between sitting time and mental health was determined using a linear regression analysis with the total or domain-specific time spent sitting as the independent variable and the mental health score as the dependent variable. Analyses were stratified by working status. Both crude and adjusted analyses were performed. To explore

TABLE 1: Characteristics of the study population ($n = 1064$).

	Total $N = 1064$ Mean ± SD	Working $N = 513$ Mean ± SD	Not working $N = 551$ Mean ± SD
Age (years)	59 ± 9	52 ± 6	66 ± 8
Gender (% men)	47.0	54.2	45.8
Education (% higher level)	23.1	27.3	19.2
Household composition (% living alone)	13.8	9.0	18.3
Occupational status (% working)	48.2	—	—
Perceived general health (% healthy)	86.6	92.4	81.1
Physical activity (h/wk)[1]	22.5 ± 14.5	22.3 ± 15.8	22.8 ± 13.2
Physical activity (% active)	58.9	61.4	56.6
Smoking (% smoker)	17.3	23.0	12.0
Alcohol (% moderate consumption)[2]	55.7	60.8	51.0
Total sitting time (h/wk)	40.9 ± 19.7	47.9 ± 21.3	34.4 ± 15.4
Domain-specific sitting time			
Transport (h/wk)	5.2 ± 6.3	7.4 ± 7.8	3.1 ± 3.3
(i) Commuting or during work (h/wk)	2.5 ± 5.6	5.2 ± 7.2	—
(ii) Leisure (h/wk)	2.7 ± 2.7	2.2 ± 1.9	3.1±3.3
At work (h/wk)	7.4 ± 12.3	15.4 ± 13.8	—
Leisure (h/wk)	28.3 ± 13.8	25.1 ± 11.9	31.3 ± 14.8
(i) Reading (h/wk)	5.5 ± 5.8	4.5 ± 4.4	6.5 ± 6.7
(ii) TV viewing (h/wk)	13.4 ± 8.3	11.6 ± 7.1	15.0 ± 8.9
(iii) Using computer (h/wk)	3.8 ± 5.1	4.0 ± 4.7	3.5 ± 5.4
(iv) Other sitting (h/wk)	5.6 ± 5.5	5.0 ± 4.3	6.3 ± 6.4
Mental health (score 0–100)	79.9 ± 14.4	81.1 ± 14.3	78.8 ± 14.4
Mental health (% healthy)	88.6	90.1	87.3
BMI (kg/m^2)	26.8 ± 4.1	26.2 ± 3.8	27.3 ± 4.2
% healthy weight	35.6	41.7	29.9
% moderately overweight	46.6	44.8	48.3
% obese	17.8	13.5	21.8

[1]Total physical activity, including light-, moderate-, and vigorous-intensity physical activity;
[2]moderate alcohol consumption is defined as 1-2 glasses per day for women and 1–3 glasses/day for men.

the role of BMI in the association, three adjusted models were applied. One included all covariates (i.e., gender, age, education, household composition, perceived health, physical activity, smoking, and alcohol) but excluded BMI (Model 1); one included all covariates and BMI (Model 2); and included an interaction term between sitting time and BMI (Model 3). The same linear regression analyses were then performed but stratified for weight status as defined by the BMI categories (healthy weight, moderate overweight, and obese adults). All analyses were performed using the SAS program, version 9.2 (SAS-Institute, Cary, NC, USA).

3. Results

3.1. Study Population. The mean age of the respondents was 59 years; the mean age of workers was 52 years versus 66 years for nonworkers (Table 1). The majority perceived their health as at least good, and 88.6% of the respondents were mentally healthy, although this was slightly higher for the working population, 90.1%. The mean BMI was 26.8 kg/m^2, and 44.8% of the working population and 48.3% of the nonworking population were moderately overweight. Approximately 13.5% of workers were obese versus 21.8% of nonworkers (Table 1). On average, the total time spent sitting across the domains was 40.9 hours per week with higher sitting times for workers than for nonworkers (47.9 hr/wk versus 34.3 hr/wk among nonworkers). Workers spent on average over 15 hours per week sitting while at work. The respondents spent most of their sitting time in leisure with an average of 28.3 weekly hours (25.1 hr/wk for workers, 31.3 hr/wk for nonworkers). TV viewing accounted for the majority of leisure sitting time ranging from 11.6 to 15.0 hours per week.

3.2. Association between Sitting Time and Mental Health. No association was found for sitting during transport or for sitting at work and mental health. For time sitting during transport, there was a significant negative interaction with BMI for the working population ($P < 0.05$) (Table 2). Among workers, the time spent sitting in leisure, and particularly

Table 2: The association between sitting time and mental health stratified by work status: results of the linear regression analysis.

	Association with mental health[1]					
	Crude		Adjusted[2]		Adjusted[3]	
	Beta	95% CI	Beta	95% CI	Beta	95% CI
Working (n = 513)						
Total	−0.04	−0.10; 0.02	−0.05	−0.12; 0.01	−0.05	−0.12; 0.01
Transport (h/wk)	−0.10	−0.26; 0.06	−0.13	−0.29; 0.04	−0.13	−0.29; 0.04
(i) Commuting or during work (h/wk)	−0.10	−0.27; 0.07	−0.16	−0.34; 0, 02	−0.15[5]	−0.33; 0.03
(ii) Leisure (h/wk)	−0.29	−0.95; 0.37	0.04	−0.61; 0.68	0.05	−0.60; 0.70
At work (h/wk)	0.04	−0.05; 0.13	0.01	−0.09; 0.11	0.01	−0.09; 0.11
Leisure (h/wk)	**−0.13**	**−0.24; −0.03**	**−0.11**	**−0.21; −0.01**	**−0.11**	**−0.21; −0.002**
(i) Reading (h/wk)	0.07	−0.21; 0.35	0.15	−0.14; 0.44	0.15	−0.13; 0.44
(ii) TV viewing (h/wk)	**−0.20**	**−0.38; −0.03**	**−0.19**	**−0.35; −0.02**	**−0.18**	**−0.35; −0.01**
(iii) Using computer (h/wk)	−0.21	−0.48; 0.05	−0.23	−0.49; 0.02	−0.23	−0.49; 0.03
(iv) Other sitting (h/wk)	−0.28	−0.57; 0.01	−0.16	−0.44; 0.12	−0.16	−0.44; 0.12
Nonworking (n = 551)						
Total	0.04	−0.04; 0.11	0.003	−0.07; 0.08	0.004[4]	−0.07; 0.08
Transport (h/wk)	0.05	−0.31; 0.42	−0.14	−0.50; 0.22	−0.13	−0.49; 0.23
(i) Commuting or during work (h/wk)	—		—		—	
(ii) Leisure (h/wk)	0.05	−0.31; 0.42	−0.14	−0.50; 0.22	−0.13	−0.49; 0.23
At work (h/wk)	—		—		—	
Leisure (h/wk)	0.03	−0.05; 0.12	0.01	−0.07; 0.09	0.01[4]	−0.07; 0.09
(i) Reading (h/wk)	0.16	−0.02; 0.34	0.01	−0.18; 0.19	−0.01[4]	−0.19; 0.18
(ii) TV viewing (h/wk)	−0.09	−0.22; 0.05	−0.04	−0.17; 0.09	−0.04	−0.17; 0.09
(iii) Using computer (h/wk)	0.32	0.10; 0.54	0.16	−0.07; 0.39	0.17	−0.06; 0.40
(iv) Other sitting (h/wk)	−0.05	−0.23; 0.14	0.03	−0.16; 0.21	0.03	−0.15; 0.22

[1]A higher MHI score indicates better mental health; thus, a negative beta indicates a negative association between sitting time and mental health; [2]Adjusted for gender, age, education, household composition, perceived health, physical activity, smoking, and alcohol consumption; [3]additionally adjusted for BMI; [4]when added to this model: $P \leq 0.05$ for a positive interaction term; [5]when added to this model: $P \leq 0.05$ for a negative interaction term.

the time spent viewing TV, was negatively associated with mental health, both with and without adjustment for BMI (β−0.11, 95% CI (−0.21)–(−0.002) for total leisure time, and ß −0.18, 95% CI (−0.35)–(−0.01) for TV viewing time, resp.). Among the nonworking population, no significant association between total time sitting, or sitting during leisure and mental health was found. However, a significant positive interaction with BMI was apparent for the total time spent sitting and leisure-time sitting ($P < 0.05$).

3.3. The Role of Weight Status in the Association between Sitting Time and Mental Health. Tables 3(a) and 3(b) present the results of the linear regression models for the association between the sitting time variables and mental health stratified by the three weight-status groups for the working (Table 3(a)) and nonworking populations (Table 3(b)), respectively. Among the obese workers, a significant negative association was found for the time spent viewing TV (model 2: β−0.43, 95% CI (−0.84)–(−0.02)). Adjustment for BMI (model 3) did not change the significant negative association (model 3: β−0.42, 95% CI (−0.83)–(−0.01)). There was no association between sitting time and mental health for the healthy weight or moderately overweight workers. Analyses among the nonworking population showed that total time sitting (β−0.16, 95% CI (−0.29)–(−0.02)) and the time spent sitting during leisure (β−0.17, 95%CI (−0.30)–(−0.03)) and viewing TV (β−0.34, 95% CI (−0.58)–(−0.11)) were all negatively associated with mental health for healthy-weight persons but not among the moderately overweight or obese persons (Table 3(b)). Among the moderately overweight and obese nonworkers, no significant associations between sitting time and mental health were observed.

4. Discussion

The results of this explorative study showed no association between time spent sitting during transport or sitting at work and mental health. Only sitting during leisure time and in particular the amount of time viewing TV were associated with a poorer mental health in the working population. Associations were even more complicated, because both work status and weight status are effect modifiers in these associations. Among nonworking persons, the total time spent sitting, the time spent sitting during leisure, and particularly viewing TV, was associated with a poorer mental health in those with a healthy weight only. In workers, the

Table 3

(a) The association between sitting time and mental health among the working population ($n = 513$) stratified by weight status: results of the linear regression analysis.

	Association with mental health[1]					
	Crude		Adjusted[2]		Adjusted[3]	
	Beta	95% CI	Beta	95% CI	Beta	95% CI
Healthy weight ($n = 214$)						
Total	−0.06	−0.15; 0.03	−0.09	−0.19; 0.01	−0.10	−0.19; 0.003
Transport (h/wk)	0.03	−0.24; 0.29	−0.03	−0.32; 0.25	−0.02	−0.31; 0.27
(i) Commuting or during work (h/wk)	0.03	−0.26; 0.31	−0.06	−0.37; 0.25	−0.05	−0.36; 0.27
(ii) Leisure (h/wk)	0.10	−1.12; 1.31	0.36	−0.86; 1.58	0.36	−0.86; 1.57
At work (h/wk)	−0.07	−0.21; 0.06	−0.09	−0.25; 0.06	−0.11	−0.26; 0.04
Leisure (h/wk)	−0.10	−0.25; 0.06	−0.11	−0.26; 0.04	−0.11	−0.26; 0.04
(i) Reading (h/wk)	−0.05	−0.46; 0.36	−0.004	−0.44; 0.43	−0.02	−0.45; 0.42
(ii) TV viewing (h/wk)	−0.02	−0.29; 0.26	−0.11	−0.38; 0.17	−0.10	−0.38; 0.17
(iii) Using computer (h/wk)	−0.19	−0.63; 0.25	−0.27	−0.72; 0.18	−0.28	−0.73; 0.17
(iv) Other sitting (h/wk)	**−0.45**	**−0.88; −0.03**	−0.35	−0.77; 0.07	−0.34	−0.77; 0.08
Moderately overweight ($n = 230$)						
Total	−0.01	−0.10; 0.08	−0.03	−0.13; 0.07	−0.03	−0.13; 0.07
Transport (h/wk)	−0.15	−0.40; 0.09	−0.20	−0.45; 0.05	−0.19	−0.44; 0.06
(i) Commuting or during work (h/wk)	−0.14	−0.40; 0.13	−0.20	−0.48; 0.07	−0.19	−0.47; 0.08
(ii) Leisure (h/wk)	−0.55	−1.48; 0.37	−0.35	−1.26; 0.56	−0.36	−1.27; 0.55
At work (h/wk)	0.10	−0.04; 0.24	0.04	−0.11; 0.19	0.04	−0.11; 0.19
Leisure (h/wk)	−0.11	−0.29; 0.06	−0.07	−0.24; 0.11	−0.06	−0.24; 0.11
(i) Reading (h/wk)	0.34	−0.19; 0.86	0.46	−0.08; 1.00	0.47	−0.07; 1.00
(ii) TV viewing (h/wk)	−0.19	−0.47; 0.10	−0.12	−0.40; 0.16	−0.11	−0.39; 0.17
(iii) Using computer (h/wk)	−0.29	−0.69; 0.12	−0.33	−0.73; 0.07	−0.32	−0.72; 0.07
(iv) Other sitting (h/wk)	−0.17	−0.63; 0.29	−0.01	−0.46; 0.43	−0.03	−0.48; 0.41
Obese ($n = 69$)						
Total	−0.08	−0.23; 0.06	−0.07	−0.25; 0.12	−0.04	−0.24; 0.15
Transport (h/wk)	−0.20	−0.58; 0.17	−0.16	−0.60; 0.27	−0.14	−0.58; 0.30
(i) Commuting or during work (h/wk)	−0.24	−0.66; 0.18	−0.23	−0.70; 0.23	−0.21	−0.68; 0.26
(ii) Leisure (h/wk)	−0.18	−1.92; 1.56	1.01	−1.16; 3.17	1.07	−1.10; 3.23
At work (h/wk)	0.09	−0.17; 0.34	0.12	−0.22; 0.47	0.17	−0.19; 0.52
Leisure (h/wk)	−0.24	−0.48; 0.002	−0.17	−0.45; 0.11	−0.15	−0.44; 0.14
(i) Reading (h/wk)	−0.03	−0.63; 0.56	0.26	−0.46; 0.98	0.33	−0.41; 1.06
(ii) TV viewing (h/wk)	**−0.50**	**−0.86; −0.13**	**−0.43**	**−0.84; −0.02**	**−0.42**	**−0.83; −0.01**
(iii) Using computer (h/wk)	−0.09	−0.72; 0.54	−0.09	−0.75; 0.56	−0.10	0.76; 0.55
(iv) Other sitting (h/wk)	−0.13	−0.86; 0.61	0.004	−0.82; 0.83	0.12	−0.74; 0.98

[1]A higher MHI score indicates better mental health; thus a negative beta indicates a negative association between sitting time and mental health; [2]adjusted for gender, age, education, household composition, perceived health, physical activity, smoking, and alcohol consumption; [3]additionally adjusted for BMI.

(b) The association between sitting time and mental health among the nonworking population ($n = 551$) stratified by weight status: results of the linear regression analysis.

	Association with mental health[1]					
	Crude		Adjusted[2]		Adjusted[3]	
	Beta	95% CI	Beta	95% CI	Beta	95% CI
Healthy weight ($n = 165$)						
Total	**−0.14**	**−0.27; −0.01**	**−0.16**	**−0.29; −0.03**	**−0.16**	**−0.29; −0.02**
Transport (h/wk)	0.26	−0.51; 1, 02	0.13	−0.66; 0.91	0.09	−0.71; 0.89
(i) Commuting or during work (h/wk)	—		—		—	
(ii) Leisure (h/wk)	0.26	-0.51;1.02	0.13	-0.66;0.91	0.09	-0.71;0.89
At work (h/wk)	—		—		—	
Leisure (h/wk)	**−0.16**	**−0.29; −0.02**	**−0.17**	**−0.30; −0.03**	**−0.17**	**−0.30; −0.03**
(i) Reading (h/wk)	−0.14	−0.38; 0.10	−0.20	−0.46; 0.06	−0.17	−0.45; 0.06

(b) Continued.

	Association with mental health[1]					
	Crude		Adjusted[2]		Adjusted[3]	
	Beta	95% CI	Beta	95% CI	Beta	95% CI
(ii) TV viewing (h/wk)	**−0.34**	**−0.57; −0.11**	**−0.35**	**−0.58; −0.12**	**−0.34**	**−0.58; −0.11**
(iii) Using computer (h/wk)	0.33	−0.10; 0.77	0.30	−0.14; 0.74	0.29	−0.15; 0.74
(iv) Other sitting (h/wk)	−0.18	−0.49; 0.13	−0.15	−0.47; 0.17	−0.16	−0.48; 0.16
Moderately overweight ($n = 266$)						
Total	**0.13**	**0.01; 0.25**	0.09	−0.03; 0.21	0.08	−0.04; 0.20
Transport (h/wk)	0.07	−0.42; 0.56	−0.13	−0.62; 0.37	−0.13	−0.62; 0.36
(i) Commuting or during work /wk)	—		—		—	
(ii) Leisure (h/wk)	0.07	−0.42; 0.56	−0.13	−0.62; 0.37	−0.13	−0.62; 0.36
At work (h/wk)	—		—		—	
Leisure (h/wk)	**0.13**	**0.01; 0.26**	0.10	−0.02; 0.22	0.10	−0.03; 0.22
(i) Reading (h/wk)	0.49	0.18; 0.81	0.30	−0.03; 0.62	0.28	−0.05; 0.61
(ii) TV viewing (h/wk)	0.04	−0.16; 0.24	0.09	−0.11; 0.29	0.09	−0.11; 0.29
(iii) Using computer (h/wk)	0.38	0.06; 0.70	0.10	−0.23; 0.44	0.09	−0.24; 0.43
(iv) Other sitting (h/wk)	−0.10	−0.42; 0.22	0.05	−0.26; 0.37	0.05	−0.26; 0.37
Obese ($n = 120$)						
Total	0.11	−0.05; 0.28	0.03	−0.14; 0.20	0.04	−0.13; 0.21
Transport (h/wk)	−0.21	−1.05; 0.62	−0.47	−1.28; 0.34	−0.46	−1.27; 0.35
(i) Commuting or during work (h/wk)	—		—		—	
(ii) Leisure (h/wk)	−0.21	−1.05; 0.61	−0.47	−1.28; 0.34	−0.46	−1.27; 0.35
At work (h/wk)	—		—		—	
Leisure (h/wk)	0.13	−0.04; 0.30	0.05	−0.12; 0.22	0.06	−0.11; 0.24
(i) Reading (h/wk)	0.37	−0.10; 0.85	−0.04	−0.56; 0.48	−0.07	−0.59; 0.46
(ii) TV viewing (h/wk)	0.02	−0.27; 0.32	−0.09	−0.39; 0.20	−0.10	−0.39; 0.20
(iii) Using computer (h/wk)	0.21	−0.26; 0.68	0.25	−0.26; 0.75	0.28	−0.23; 0.78
(iv) Other sitting (h/wk)	0.20	−0.16; 0.56	0.24	−0.11; 0.59	0.31	−0.05; 0.67

[1] A higher MHI score indicates better mental health; thus, a negative beta indicates a negative association between sitting time and mental health; [2] adjusted for gender, age, education, household composition, perceived health, physical activity, smoking, and alcohol consumption; [3] additionally adjusted for BMI.

association between viewing TV and poorer mental health was also apparent among the obese workers only.

There are some mechanisms that may explain a relationship between sitting and the risk for poor mental health. First, the favorable effects of physical activity on mental health, especially on depression, have been well documented [22, 24, 34]. If sedentary behaviors substitute time spent on physical activity, the favorable mental health effects of physical activity cannot occur. The negative association found for overall leisure time and TV viewing with mental health is in line with this mechanism; however, the lack of an association between sitting in general and mental health does not support this explanation. Another mechanism refers to the social withdrawal hypothesis, which proposes a positive association between TV viewing time, removal from social interaction, and a subsequent increased risk of depression [35]. This theory is likely also valid for a general form of mental health problems. The association found in the present study for TV viewing and poorer mental health supports this hypothesis. In addition, the lack of an association for sitting at work and mental health may also support the social withdrawal hypothesis, since most jobs take place within a social context. The finding that the association between sitting and mental health in particular exists for time spent TV viewing might also be explained by the mechanism that TV viewing can be associated with energy-dense snack consumption and snacking behavior, both of which are known to be related to obesity [20, 21]. Moreover, as a possible explanation, depressive symptoms have been associated with unhealthy food choices, leading to weight gain and, in the longer term, obesity [36, 37]. Thus, the association between TV viewing and poorer mental health among the obese workers may be explained by the related unhealthy food consumption while viewing TV. All in all, considering the findings that—in case of significant associations—leisure time sitting and especially TV viewing was consistently associated with poorer mental health status, it can be argued that it may be the context of the sitting rather than the length of sitting time that is important in the association with mental health.

A notable finding of our study is the role of weight status with a clear association between the time spent viewing TV and poorer mental health among healthy weight nonworkers as well as among obese workers. A possible explanation for the differing associations found by weight status among workers is that obese workers consume more unhealthy food and beverages when viewing TV (compared to the healthy weight and moderate overweight workers), which may make them feel guilty, decrease their self-esteem, and negatively impact their mental well-being. However, it should be emphasized that the current status of knowledge in this field is explorative, and an obvious explanation for the present findings cannot be given. Instead, more research is necessary to investigate the relationships suggested by this explorative study before elaboration.

A few weaknesses and strengths of this study need to be highlighted. First, the data on sedentary behaviors were derived by means of self-report, which challenges reliability and validity [35]. As is well known, subjective methods or self-reports are likely to produce biased measures of the behavior of concern, that is, the amount of sedentary behavior. Because of the increasing awareness of the role of sedentary behavior, it was decided to measure sitting time in the fifth round of the Doetinchem cohort. For the present study, we used sedentary behavior questions that were in line with the structure and format of the physical activity questions. The latter were designed for inclusion in the EPIC study and appeared to be of satisfactory reproducibility and relative validity [28]. Currently, the psychometric characteristics of these sitting questions are unknown, and, until we have better data, future population-based research on sedentary behaviors should develop reliable and valid measurements for various sedentary behaviors. For the present study, we treated the available variables for sitting time rather conservatively, analyzing only respondents with complete data (i.e., no missing values for any variables of sitting time). This helped to ensure a stable dataset. Although the participants were asked to their working status, no further questions on the profession or job roles were included, which can be considered as a limitation of a study. Further, the respondents of the Doetinchem Cohort study may not be fully representative of the Dutch population because respondents live in one (rural) town in the Netherlands and had a very healthy profile with, for instance, a low prevalence of mental illness, which might also have challenged the power of the analyses. The selection of workers may not be compared to the general Dutch working population as the workers in the current study were considerably younger than the nonworkers (who averaged 66 years). This may have resulted in disparate (sedentary) time-spending patterns and health status, simply and solely due to age. However, as the age-adjusted analyses did not show notable differences, we believe the age-related impact on the results is negligible. We examined the associations by linear regression analyses and used a continuous measure for sitting behavior. However, it can be argued that the association between sitting time and mental health is not linear, that is, an increased risk for poorer mental health related to an increase in each weekly sitting hour. Instead, using tertiles or another way of categorizing, the amount of sitting time may have shown significant associations given a certain cutoff point for sitting time. In an additional analysis, we examined the associations for categories of TV viewing (<2 hr/day versus ≥2 hr/day), but this did not change the conclusions (data not shown). It is clear that more research is necessary. First, it is recommended that longitudinal research be performed to confirm the current findings and examine the direction of the relationship. Additionally, it would be more than interesting to test potential behavioral mechanisms. To specify, future research is needed to investigate the mediating role of physical activity, dietary habits, work status, and overweight in the relationship between sedentary behavior and mental health. Finally, as mentioned earlier, the development of reliable and valid measurements covering the entire range of sedentary behaviors is strongly recommended. On the other hand, this study is innovative as it explored the associations between various sedentary behaviors in domains where people spend a substantial part of their day and poor mental health. Another strength is that we used body weight and height, measured by trained and experienced assistants.

In conclusion, the present explorative study confirms the relationship between TV viewing time and poor mental health as suggested in earlier studies, with BMI and working status being effect modifiers, but this association does not hold for spending time in other domains of sitting. Further longitudinal research is needed to confirm the results and to determine the causality in the relationship between sedentary behaviors and mental health. In addition, our data suggest that work status and weight status should be taken into account when studying the relationship between sitting and mental health.

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Research Article

Do Motion Controllers Make Action Video Games Less Sedentary? A Randomized Experiment

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Sports- and fitness-themed video games using motion controllers have been found to produce physical activity. It is possible that motion controllers may also enhance energy expenditure when applied to more sedentary games such as action games. Young adults ($N = 100$) were randomized to play three games using either motion-based or traditional controllers. No main effect was found for controller or game pair ($P > .12$). An interaction was found such that in one pair, motion control (mean [SD] 0.96 [0.20] $\text{kcal} \cdot \text{kg}^{-1} \cdot \text{hr}^{-1}$) produced 0.10 $\text{kcal} \cdot \text{kg}^{-1} \cdot \text{hr}^{-1}$ (95% confidence interval 0.03 to 0.17) greater energy expenditure than traditional control (0.86 [0.17] $\text{kcal} \cdot \text{kg}^{-1} \cdot \text{hr}^{-1}$, $P = .048$). All games were sedentary. As currently implemented, motion control is unlikely to produce moderate intensity physical activity in action games. However, some games produce small but significant increases in energy expenditure, which may benefit health by decreasing sedentary behavior.

1. Introduction

Sedentary screen time is a major public health problem. Sedentary behavior, particularly television (TV) watching, presents unique risks for obesity and related negative health outcomes in addition to risks from inactivity [1, 2]; even individuals who are very active show increased metabolic risk with higher amounts of TV watching [3]. Sedentary video gaming has also been implicated as a predictor of obesity [4, 5]. Video gaming using motion-based controllers has been proposed as a less sedentary alternative to TV watching or traditional video gaming [6], but these games vary widely in physical activity level produced during play. One factor that appears to have a large influence on energy expenditure is the type of controller used: for instance, dance and fitness-themed games using dance mat and camera-based controllers consistently show higher levels of activity during play when compared to games that use more traditional gamepad controllers [6–11]. This difference is to be expected, as gamepads rely on small finger movements, whereas other control schemes engage large muscles in the arms and legs. Though dance and fitness-themed games are popular, action games remain the most widely played genre [12]. Action games typically emphasize skill, reflexes, and speed, and many of the most enduring video game franchises fall under this category; examples include games that require jumping across platforms (e.g., *Super Mario Bros.* and its many sequels) or precisely shooting or punching enemies (e.g., games in the *Call of Duty* or *Street fighter* series).

Integration of greater bodily motion into these traditional action video games may be a way to increase energy expended during play while retaining the features that make these games popular. Supplanting button presses for more realistic mimicking of, for example, punching or sword-fighting would not necessarily change engaging aspects of these games (storyline, skill-testing gameplay, graphics, etc.).

Motion control has even been hypothesized to potentially make games more engaging [13]. The Nintendo Wii console comes packaged with a Wiimote controller, which includes both buttons and motion-sensing functionality. Many action games can be played on the Wii console, but Wii versions of the games generally change the control scheme to include motion control for such actions as aiming a weapon or throwing grenades. It is as yet unclear whether these motions produce greater energy expenditure than typical button presses in traditional games. If motion controllers produce greater energy expenditure than traditional controllers, they could produce positive health impacts at both the individual and public health level.

The purpose of this study was to investigate the effects of motion-sensing controllers on energy expenditure during play of games from the action genre. Participants were randomized to play three games using either motion controllers or traditional controllers. The two games in each pair were different versions of the same game to minimize the presence of potential confounding variables. Enjoyment was also measured to investigate potential differences between controller groups. It was hypothesized that motion-controlled games would produce greater energy expenditure than the traditionally controlled games.

2. Materials and Methods

2.1. Study Participants and Protocol. Participants were 100 18–35-year olds, equal numbers of men and women, recruited primarily through a university online mailing list. The recruitment e-mail specifically solicited those interested in a video game research study. Participants were also recruited via a general weight-related study advertisement for 18–35-year olds shown on a local news network that directed interested viewers to a website with study descriptions and contact information. To be included, participants were required to weigh <300 pounds (necessary for the use of other game controllers in a larger study discussed elsewhere) [14], have played video games at least 3 times over the past year, be willing to fast 2.5 hours (necessary for indirect calorimetry), be videotaped during the study protocol, and have transportation to the study location. Of 757 individuals who requested information and eligibility criteria, 325 completed eligibility information; of those 325, 169 potential participants were scheduled, and 100 completed the protocol. Eligible participants who did not attend their appointments ($N = 49$) were considered dropouts, 156 eligible participants were wait-listed, and 20 participated in a sub-study not reported here. All data were collected between April and August of 2009.

After providing informed consent, anthropometric measures (height, weight) were taken in light street clothes without shoes. Demographic variables were assessed via a pre-experimental questionnaire. Participants were next led to a darkened video gaming laboratory and fitted with measurement equipment, then rested for 20 minutes. Controller type (traditional gamepad or motion Wiimote motion controller) was assigned randomly using a random number generator, and games were played in random order. Each game was played initially for a three-minute training period. All participants were provided with a visual aid to assist in learning controls, and study staff gave a brief introduction to the basic story and mechanics of the games. Once this period was complete, participants played for 10 minutes. Self-report variables were measured immediately after play of each game by questionnaire. Additionally, participants were randomized to play several other types of games either before or after these games as part of a larger study [14]. Tests of the effects of game order and play of other games prior to this study on energy expenditure did not show significant effects (data not reported).

Games were played on a 58″ high-definition television with optimized settings for each console. Participants sat in a gaming chair with speakers in the headrest that provided surround sound. The chair was placed approximately six feet from the television. Snack foods and drinks were available immediately after data collection concluded and water was available during rest periods. This protocol was approved by the University of North Carolina Public Health-Nursing Institutional Review Board.

2.2. Games. All participants played three games. Participants were randomized to play three games using either a button-based traditional gamepad controller or a motion-based Wiimote controller. All games were part of the broad genre of action games, rated M for Mature, and released between the years of 2002 and 2007.

Game pairs were chosen to represent different player perspectives, to investigate the effects of perspective and controller on psychological reactions not reported here. Figure 1 shows the study design. *Medal of Honor: Heroes 2* and *Medal of Honor: Airborne* used a first-person perspective (i.e., players see through the eyes of their character), while *Resident Evil 4: Wii Edition* and *Resident Evil 4* used an over-the-shoulder perspective (players view the game environment from over the shoulder of their character). The final pair was chosen to vary both controller as well as perspective, and thus these two games were not as similar than the games in the other pairs. *Resident Evil* used a third-person perspective and a traditional controller, and *Resident Evil: The Umbrella Chronicles* used a first-person perspective and a motion controller.

The controllers used for the traditional play condition were the Playstation 3 (PS3) Dualshock controller and the Gamecube controller. Both controllers were of the traditional button-based gamepad type. The motion-sensing controllers used were the Wiimote and Nunchuk combination. The Wiimote, shaped like a remote control, was held in the right hand and used for both button and motion-based inputs. The Nunchuk was held in the left hand and used only for its button-based inputs.

2.3. Measures. Energy expenditure was measured via indirect calorimetry (Ultima CPX, MEDGRAPHICS, St. Paul, MN) using a neoprene mask and open Pneumotach. The indirect calorimeter was calibrated daily using a 3-liter syringe as well as prior to each test using certified gases. Oxygen consumption (VO_2) and carbon dioxide expiration (VCO_2)

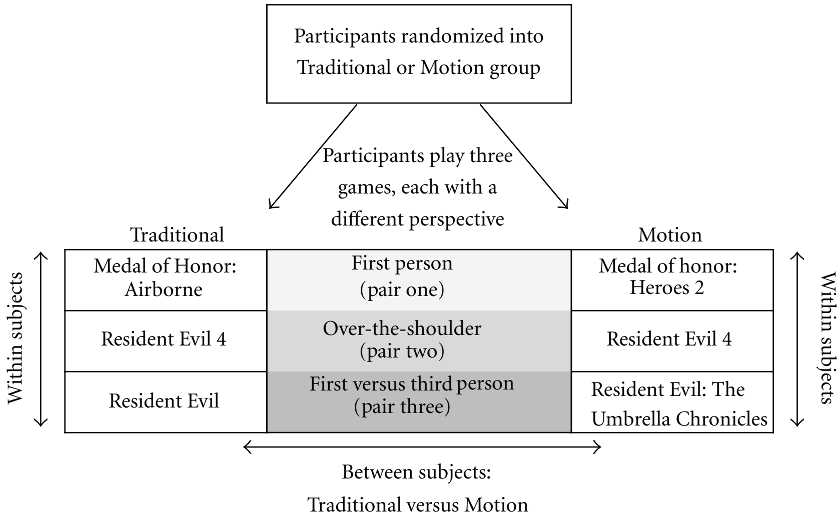

Figure 1: Study design.

were measured on a breath-by-breath basis and converted to energy expenditure. Enjoyment was measured using the interest/enjoyment subscale of the Intrinsic Motivation Inventory, which is a well-validated measure that has been used in previous virtual reality physical activity studies [15, 16]. This scale consisted of seven questions with responses on a Likert scale of 1–7. Participants were also asked about their general previous experience playing video games ("how much experience do you have playing video games?" with responses ranging from 1, not a lot, to 7, a lot) and whether they had played each of the games previously (dichotomous yes/no response). Weight and height were measured using a calibrated scale (Tanita, Arlington Heights, IL) and wall-mounted stadiometer (Perspective Enterprises, Inc., Kalamazoo, MI).

2.4. Data Preparation and Analysis. Energy expenditure data were averaged over the ten-minute play period and corrected for body mass ($\text{kcal}\cdot\text{kg}^{-1}\cdot\text{hr}^{-1}$, equal to metabolic equivalents or METs). Cut-points for sedentary behavior and light and moderate physical activity were taken from Pate et al. [17]. Energy expenditure <1.5 METs was considered sedentary. Two mixed models (dependent variables energy expenditure and enjoyment) were created, with game pair as a repeated measure and controller condition as an independent variable. Degrees of freedom were calculated using the Kenward-Roger method, and all tests of mean differences took into account row-wise degrees of freedom. Because several studies of energy expenditure during video game play have found effects of BMI and gender [11, 18], these variables were included in the model. The expenditure model was also run a second time with enjoyment as a covariate. Interaction terms for game pair × controller condition were also included. To investigate interactions, post hoc contrasts with Tukey-Kramer corrections were used. Games were contrasted within pairs and/or with the other games in their controller group (motion or traditional). Independent sample t-tests were also used for simple comparisons between groups, analyses of variance for tests of the impact of playing the game previously, and correlation analysis was used to investigate bivariate associations. The SAS software package (Cary, NC) version 9.2 was used for all analyses.

3. Results

Table 1 displays participant characteristics. The sample was 73% White, 15% Black, 8% Asian, and 4% other race. Six participants were of Hispanic ethnicity. Most participants were college graduates (49%), followed by those with some college education (32%). There were no significant differences between groups on any sociodemographic variables. Fifty-five percent of participants were overweight. Most participants had not played the games previously: 18 of the 100 had played Resident Evil, 25 had played Resident Evil 4, and 18 had played Medal of Honor. No differences in previous play were found by controller. No association was found between energy expenditure and video game playing experience or previous play of each game ($P > .05$). Video game playing experience was positively associated with enjoyment (Resident Evil, $r = .255$, $P = .011$; Resident Evil 4, $r = .307$, $P = .002$; Medal of Honor, $r = .264$, $P = .008$). Having ever played the game before predicted enjoyment in Resident Evil ($B = 0.91$, SE $= .63$, $P = .006$) and Medal of Honor ($B = 1.62$, SE $= .63$, $P < .001$) but not Resident Evil 4 ($B = 0.54$, SE $= .51$, $P = .101$).

Mean energy expenditure corrected for body mass for each game is shown in Table 1. No main effect was found for controller ($P = .121$) or game pair ($P = .510$). However, an interaction between controller and game pair was found ($P = .004$). The motion-controlled Resident Evil game (mean [SD] 0.96 [0.20] $\text{kcal}\cdot\text{kg}^{-1}\cdot\text{hr}^{-1}$) produced 0.10 (95% confidence interval [CI] 0.03–0.17, $P = .048$) $\text{kcal}\cdot\text{kg}^{-1}\cdot\text{hr}^{-1}$ greater energy expenditure than its comparison, the traditionally controlled Resident Evil game (0.86 [0.17] $\text{kcal}\cdot\text{kg}^{-1}\cdot\text{hr}^{-1}$). Within the motion-controlled condition, the Resident Evil game produced 0.06 (95% CI 0.02–0.11, $P = .030$) $\text{kcal}\cdot\text{kg}^{-1}\cdot\text{hr}^{-1}$ greater energy expenditure than Resident Evil 4 (0.90 [0.18] $\text{kcal}\cdot\text{kg}^{-1}\cdot\text{hr}^{-1}$). No other

Table 1: Participant characteristics and energy expenditure and enjoyment outcomes by condition, mean (SD).

Characteristic	Traditional ($N = 50$)	Motion ($N = 50$)	Total ($N = 100$)
Age	23.78 (4.02)	23.74 (3.95)	23.76 (3.96)
Height (cm)	171.65 (10.76)	173.12 (8.77)	172.38 (9.79)
Weight (kg)	79.44 (20.65)	81.37 (20.74)	80.40 (20.62)
BMI (kg/m^2)	26.82 (6.02)	27.42 (7.04)	27.12 (6.52)
Experience	5.80 (1.36)	5.90 (1.21)	5.85 (1.28)
Energy expenditure (kcal$\cdot$kg$^{-1}\cdot$hr^{-1})			
Rest	0.76 (0.18)	0.78 (0.17)	0.77 (0.18)
Resident Evil	0.86 (0.17)*	0.96 (0.20)*	0.91 (0.19)
Resident Evil 4	0.90 (0.17)	0.90 (0.18)	0.90 (0.18)
Medal of Honor	0.90 (0.19)	0.93 (0.19)	0.91 (0.19)
Overall (across game)	0.89 (0.16)	0.93 (0.17)	0.91 (0.16)
Enjoyment			
Resident Evil	2.97 (1.40)*	4.38 (1.40)*	3.68 (1.56)
Resident Evil 4	4.29 (1.38)**	4.08 (1.61)	4.19 (1.50)
Medal of Honor	4.48 (1.74)**	4.15 (1.74)	4.32 (1.74)

cm: centimeter; kg: kilogram; m: meter; kcal: kilocalorie; hr: hour.
*Significant difference by controller, $P < .05$.
**Significantly different from traditionally controlled Resident Evil, $P < .001$.

energy expenditure differences between games in a pair or within controller condition were found ($P > .30$).

Participants with a higher BMI expended less energy during play than those with a lower BMI, B (SE) $= -0.01$ (0.00), $P < .001$. Energy expenditure did not differ by gender ($P = .645$). All six games produced energy expenditure estimates below 1.5 kcal$\cdot$kg$^{-1}\cdot$hr^{-1} (equal to METs), indicating that all were sedentary [17].

Analyses of enjoyment ratings found significant differences by game ($P < .001$) as well as an interaction between game and console ($P < .001$). The motion-controlled Resident Evil game produced a 1.39 (95% CI 0.84–1.95) point higher enjoyment rating (on a scale of 1–7) than the traditionally controlled Resident Evil game. The other two traditionally controlled games were also rated as more enjoyable than the traditionally controlled Resident Evil game (Resident Evil 4, mean difference 1.32, 95% CI 0.84–1.80; Medal of Honor, mean difference 1.51, 95% CI 1.03–1.99). No other significant differences were found. Males ($B = 1.19$, SE $= 0.20$, $P < .001$) and those with higher BMI ($B = 0.03$, SE $= 0.01$, $P = .028$) rated the games as more enjoyable than females and those with lower BMI.

Inclusion of enjoyment as a covariate in the energy expenditure model slightly attenuated but did not alter the significance of the interaction between game pair and controller type ($P = .026$). Enjoyment was not associated with energy expenditure in any of the game pairs ($P > .60$), and this result did not differ by controller group.

4. Discussion

Contrary to our hypothesis, play of action games with motion-sensing controllers did not produce greater energy expenditure than play of similar games with traditional gamepad controllers. The traditional and motion-controlled games studied here produced average energy expenditures of 0.89 and 0.93 kcal$\cdot$kg$^{-1}\cdot$hr^{-1}, respectively, representing increases of 22 and 25 percent over rest measurements. In only one of three game pairs did the motion-controlled version produce significantly greater energy expenditure than a traditionally controlled version, a difference of 0.10 kcal$\cdot$kg$^{-1}\cdot$hr^{-1}. However, that game also produced greater energy expenditure than another of the motion-controlled games, suggesting that *how* motion controls are integrated into gameplay likely influences the intensity of motions used and thus energy expenditure.

Some motion-controlled games hold potential to significantly increase energy expenditure during screen time as compared to similar traditionally controlled games [19]. However, results of this study, showing only one of three games increasing expenditure, suggest that many action games likely do not. The results further suggest that the simple addition of motion control to traditional games, such as action games, is not sufficient to produce light or moderate intensity physical activity and will not consistently produce an improvement in activity intensity as compared to traditional controllers.

Replacement of traditional controllers with motion controllers during play of action games could positively affect health in several ways. Even very low intensity muscle contractions, such as those involved in standing, can prevent or negate metabolic changes that result from sedentary behavior [20, 21]. Additionally, the muscle contractions necessary to play motion-controlled action games may interrupt longer stretches of sedentary gaming. Breaks in sedentary time, regardless of their length or intensity, are associated with lower waist circumference, BMI, triglycerides, and 2-hour plasma glucose independent of total sedentary time and moderate-vigorous activity [22]. In other words, even the smallest periods of very light intensity activity can be beneficial, particularly if they interrupt what would otherwise be a long session of sedentary behavior. Thus, the motions required for play of motion-based action video games, though not strenuous enough to produce light intensity activity, may be sufficient to reduce risk associated with sedentary screen time.

Previous studies have found that use of the Wiimote motion-sensing controller can produce light (1.5–3 METs) to moderate (>3 METs) intensity physical activity in several specific fitness- and sports-themed games (e.g., Wii Sports and Wii Fit), increasing energy expenditure over rest up to 328% [18, 23]. Though the Wii games studied here used the same controller as the games previously studied, due to our study design, they more closely resembled traditional sedentary games in both content and energy expenditure [6, 24]. The motions encouraged by games like Wii Sports differ greatly from those encouraged by other Wii action games. Whereas Wii Sports encourages large, exaggerated movements such as swinging a tennis racket or punching an opponent, action games require greater precision of movement to ensure success. The game that showed the greatest energy expenditure in this study (Resident Evil: The Umbrella Chronicles) encouraged frequent shooting by offering unlimited ammunition for the default weapon. It may be that the abundance of ammunition (a rarity in action games, which often require management of scarce resources to increase suspense) allowed participants to shoot more often than they did in the other games and, thus, expend more energy. Though Resident Evil 4: Wii Edition, which produced significantly lower energy expenditure than The Umbrella Chronicles, also used motion controls, it required more precise shooting less often and placed a greater emphasis on exploration of the game environment, which did not require player motion. Even if motion controls are added to this genre of game, it may be that the characteristics of the genre itself generally discourage unnecessary movements.

The game that produced the lowest energy expenditure (traditionally controlled Resident Evil) was also rated less enjoyable than its comparison motion-controlled game as well as the other two traditionally controlled games. This finding was surprising, as Resident Evil is considered a classic game, and the version used (the 2002 Gamecube remake) received extremely high review scores. Enjoyment was also predicted by overall gaming experience and having played the game before in Resident Evil and Medal of Honor games. It is unclear whether previous experience leads to increased enjoyment due to familiarity or if previous play and enjoyment both reflect an underlying variable such as a preference for specific types or series of games.

A strength of this study was the experimental study design and inclusion of three different pairs of games. To our knowledge, this study was the largest one of motion-controlled gaming yet conducted, with a much larger proportion of female participants (50%) than in past studies. As women represent approximately 40% of video game players [12], their inclusion in active gaming studies is important. Participants were randomized to play iterations of the same game using different controllers, eliminating many potential confounding variables related to game content that may have biased previous studies.

A limitation of the study was that only one of the three pairs included identical games. The other two pairs included games that were chosen to minimize potential confounding variables; however, it was impossible to eliminate them. The pair that produced significant differences in energy expenditure, Resident Evil and Resident Evil: The Umbrella Chronicles, was the least similar of the three pairs. The games shared characters, storyline, and setting, but differences in implementation of control scheme may have led to differences in gameplay. Differences in this pair (e.g., more frequent shooting, greater enjoyment), offer insight into possible variables to manipulate in future studies that may produce increases in energy expenditure.

Other limitations include the cross-sectional nature of the data and measurement of only one side of energy balance. It is impossible based on this study design to determine potential effects of game play on subsequent energy intake and expenditure. Play of video games with a traditional controller has been found to increase food consumption after a play session [25]; thus, it is possible that later increases in energy intake could erase the expenditure benefits of motion-controlled action gaming and result in overall positive energy balance. Results should also be generalized with caution due to possible differences between eligible participants who completed the study and those who did not attend their appointment or who were eligible but not asked to participate because recruitment goals (i.e., 100 participants, 50 per gender) were reached.

5. Conclusions

Action video games are extremely popular and are the most widely played genre of video game. Addition of motion controls to this genre of game can produce small increases in energy expended during play. However, only some motion-controlled action games produce greater expenditure than equivalent traditionally controlled games; these games also produce greater energy expenditure than some other motion-controlled games. The manner in which motions are integrated into gameplay likely has a large effect on the amount of energy expenditure than can be expected during play. Though motion-controlled action games may not lead to changes in the intensity of physical activity, their potential for reducing risk associated with sedentary behavior should not be overlooked.

Little is currently known about the impact of motion-controlled games on sedentary behavior and physical activity over time. Even less is known about the impact of these games on other behaviors that may be associated with obesity and other negative health outcomes, such as snacking during screen time. There is a particular need for investigation of game characteristics that encourage or discourage movement even in highly similar games, such as the two motion-controlled Resident Evil games played in this study that produced significantly different energy expenditure levels. Randomized controlled trials are necessary to investigate the potential of games to contribute to obesity prevention and treatment; even games that do not increase moderate-vigorous intensity physical activity may improve health by decreasing prolonged bouts of sedentary behavior.

Conflict of Interests

The authors declare that they have no competing interests.

Authors' Contributions

E. J. Lyons and D. F. Tate designed the study and obtained funding. E. J. Lyons, D. F. Tate, and J. M. Bowling planned and performed statistical analyses, and all authors participated in interpretation of analyses. E. J. Lyons drafted the paper. D. F. Tate, D. S. Ward, K. M. Ribisl, J. M. Bowling, and S. Kalyanaraman critically revised the paper. All authors read and approved the final paper.

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Research Article

Television Viewing Does Not Have to Be Sedentary: Motivation to Participate in a TV Exercise Program

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The present study explored which underlying motivations induced people to participate in a television exercise program called "The Netherlands on the Move!-television" (NOM-tv). A cross-sectional study was carried out among 1,349 viewers of NOM-tv. The respondents completed the intrinsic motivation inventory (IMI), assessing their levels of intrinsic motivation towards participating in the NOM-tv exercises. The results showed that higher levels of intrinsic motivation (i.e. enjoying the NOM-tv exercises, feeling competent to perform this activity, and willingness to put effort into the exercises) were the most important predictive factors of more frequent participation in the NOM-tv exercises. Future screen-based interventions to reduce sedentary behavior should aim especially at encouraging people's intrinsic orientations towards physical activity in an autonomy-supportive way.

1. Introduction

Sedentary behavior has been found to be a predictor of weight gain [1], type 2 diabetes [2], cardiometabolic risk [3], specific cancers [4], cardiovascular diseases [5], and all-cause mortality and cardiovascular mortality [6–8]. Despite the evidence, sedentary lifestyles are increasing in most Western countries [9]. For older adults, increased physical activity is particularly important to reduce the risk of chronic illnesses and to maintain mobility, prevent falls, and improve health-related quality of life [10–12].

In 1995, the Dutch government decided to launch a national campaign called "The Netherlands on the Move" [13]. One part of this campaign was the introduction of a national daily television program in 2000, called "The Netherlands on the Move!-television" (NOM-tv). Various national health organizations (such as the Dutch Heart Foundation, Netherlands Institute for Sport and Physical Activity, Netherlands Brain Foundation, and Dutch Cancer Society) joined forces and initiated and coproduced this television program. NOM-tv was designed for adults (mainly targeting people aged 55 and over), to offer them an easily accessible, low-intensity, exercise facility: morning exercises being performed at home in front of the television. Whereas television viewing is typically considered to be a sedentary behavior, participation in NOM-tv can in fact be a first step towards a reduction of daily sitting time. NOM-tv shows that television viewing does not always have to be sedentary and this program may be regarded as an innovative way for health promotion interventions to make use of the popularity of screen viewing to reduce sedentary behavior.

NOM-tv is broadcast via the Dutch nation-wide public-service broadcasting system. Over the years, NOM-tv has been continuously optimized by frequent process evaluations (formative research) among program viewers. NOM-tv is a popular television program, with approximately 137,000 viewers a day [14]. The program is broadcast on weekdays at 6.45 a.m. and 9.10 a.m. and with a replay on Saturdays and

Sundays at 8.45 a.m. The program lasts 15 minutes and starts with a general health education message. This is followed by five physical activity blocks which viewers can actively take part in at home: (1) warmingup; (2) arms-legs coordination; (3) cardiofitness; (4) muscular strength; (5) cooling-down. Two instructors take turns leading the exercises of an exercise group of five persons in the studio. The members of this exercise group, participating in the exercises in the background, are carefully selected. Both obese and nonobese, males and females, young and old participants, native as well as people from other ethnic origins are performing the exercises in the background, as a result of which all viewers can identify themselves with these role models. The program ends with a short feature highlighting various physical activities and sports. A popular activity such as line dancing may be introduced, or information is provided about being active when suffering from diseases such as cancer or osteoarthritis, or an upcoming sports event may be announced. NOM-tv is supported by a Web page, and DVDs have been released.

Hopman-Rock et al. [15] identified determinants of participation in NOM-tv in a cohort study among an age stratified quota sample (random digit dialing throughout the Netherlands) of people aged 35–55 years and 55 years and over. The study gave insight into the characteristics of viewers and nonviewers. The researchers found that NOM-tv particularly appealed to older women who perceive few barriers to participation and have a reasonable knowledge about the benefits of physical activity. Furthermore, the program also seemed particularly appealing to people at the lower stage of change levels. Hopman-Rock et al. [15] therefore concluded that NOM-tv contributes to compliance with the physical activity guidelines by people who are generally difficult to reach.

Mass media campaigns can be seen as a means to raise awareness about physical activity and health in the general population [16]. Although several mass media campaigns have effectively promoted physical activity by educational messages through various mass media channels [16, 17], no previous research has been conducted into the factors that explain participation in physical activity programs on television.

According to the Self-Determination Theory [18], participation in physical activities can lead to feelings of enjoyment, personal challenge, and a sense of competence about being physically active. These motives to engage in exercise are likely to be perceived as autonomous and reflect intrinsic motivation to exercise. For people having such intrinsic orientations towards exercise, participation is likely to be accompanied by a sense of volition and freedom from pressure. Furthermore, engaging in exercise will be accompanied by positive exercise-related cognitions and affect, and long-term commitment can be expected. On the other hand, some people tell themselves, for instance, that they "*must* exercise to lose weight". Types of exercise motivation such as improving appearance or pleasing others are more likely to be perceived as internally controlling, which reflects extrinsic motivation. When someone has internally controlling motives, exercising will be accompanied by feelings of tension and pressure to act. As a result, long-term commitment is less likely [19, 20]. Empirical research supports these tenets of the Self-Determination Theory in an exercise context: greater enjoyment, higher perceived competence, and autonomous exercise motivation are significantly associated with higher physical activity levels [21–27]. Even with regard to exercise adherence over time, empirical evidence shows a positive association between autonomous motivation and sustained exercise participation [25–27].

The development of NOM-tv was based on the Social Cognitive Theory [28]. Observational learning, the process of learning which occurs when a person watches the actions of another person and the reinforcements that the person receives, is a central idea of the Social Cognitive Theory. Observational learning is part of social modeling, which is one of the four means to increase self-efficacy [29]. In NOM-tv, social modeling is operationalized by the instructors who function as role models and give instruction and guidance on how to perform the NOM-tv exercises. Besides, the program involves a wide variety of people exercising in the background, who can as well be viewed as important role models. Viewers are likely able to identify with some of the background exercisers. Observational learning asserts that viewers can witness observed behaviors of the background participants and then reproduce the same actions. As a result of this, behavioral capability and self-efficacy are enhanced. In the development of NOM-tv the difficulty level of the exercises has also been taken into account and during a pilot of the program the difficulty level of the exercises was adjusted to the target population. The exercises should be executable in the living room and be both performable for healthy people, as well as for viewers with minor health problems such as reduced mobility or asthma. These people are advised to use a chair for the exercises which is also demonstrated by some background participants.

The main goal of the present study was to explore which underlying motivations were associated with participating in the NOM-tv exercises. Since providing role models and enhancing self-efficacy and behavioral capability are central goals of NOM-tv, it can be expected that participation in the NOM-tv exercises can lead to an increased sense of competence about being physically active. Therefore, we hypothesized a positive relationship between perceived competence and participation in NOM-tv. We assessed motivational regulation by means of the intrinsic motivation inventory (IMI; [26, 30]), an instrument based on the Self-Determination Theory. The IMI determines respondents' levels of intrinsic motivation as an additive function of six underlying dimensions (interest-enjoyment, perceived competence, effort-importance, pressure-tension, perceived choice, and value-usefulness). The instrument has gained widespread acceptance as a multidimensional measure of intrinsic motivation in the context of sports and physical activity [26, 30–33]. Based on the Self-Determination Theory, our second hypothesis was that respondents, who perceived more autonomous motives to engage in the NOM-tv exercises, would also participate more often in the NOM-tv exercises.

2. Method

2.1. Design of the Study. A cross-sectional study was carried out among viewers of NOM-tv. In accordance with Dutch ethical guidelines, approval by an ethics committee was not requested for this survey study. Participants were informed that all provided information would be treated confidentially and would only be used anonymously for research purposes. Respondents were recruited through the Web page of the Dutch public channel which broadcasts NOM-tv (MAX), and through several other Web pages of partner organizations that help coordinate NOM-tv (including the Netherlands Institute for Sport and Physical Activity and the Dutch Heart Foundation). The recruitment took place from May 18 until June 30, 2009. During this period, 1,737 viewers of NOM-tv completed the questionnaire. Viewers who participated in the NOM-tv exercises and had less than eight missing values on the IMI were included in this study. This brought the total number of respondents in this study to 1,349 people (77.7%). Missing values were replaced by the item mean scores.

2.2. Measures

2.2.1. Basic Characteristics. The questionnaire addressed the following background variables: gender, age, marital status, current occupational status, and nationality. Body mass index (BMI) in kilograms per square meter was calculated from self-reported weight (kg) and height (m). Respondents were asked to report their educational level, which was categorized into low (no education, primary, or lower vocational school) and high (secondary vocational school, high school, higher professional education, or university). The level of urbanization was defined by whether respondents reported to live in a town or city, or in a village. Perceived personal health status was measured by asking respondents to rate their perceived health on a scale from 1 to 10 (with 10 representing the most positive score).

Respondents were also asked to report how many minutes a day they had spent performing mildly intensive, moderately intensive, and highly intensive physical activities on average during the past week, based on the validated *Short Questionnaire to Assess Health Enhancing Physical Activity* (SQUASH) [34]. For example with regard to the question how much time a day people spent on average in the past week on moderately intensive physical activities (like dancing, working in the garden, etc.), respondents could answer 0 minutes a day (1), less than 30 minutes a day (2), 30–60 minutes a day (3), 1-2 hours a day (4), or more than 2 hours a day (5). The scores on the variables measuring moderately intensive and highly intensive physical activities were summed to determine whether people were at least moderately physically active for a minimum of 30 minutes a day. Respondents who answered option 3 (or higher) on one or both variables were classified as meeting the Dutch physical activity guidelines, which state that every adult should accumulate 30 minutes or more of moderately intense physical activity on at least five, preferably all, days of the week [35].

Viewing habits were measured by asking how many times a week respondents watched NOM-tv. The answering categories were “less than weekly (1)”, “1-2 times a week (2)”, “3-4 times a week (3),” and “5–7 times a week (4)”.

2.2.2. Intrinsic Motivation Inventory. The Intrinsic Motivation Inventory was used to measure respondents’ subjective experience with regard to participation in the NOM-tv exercises, measured in six dimensions. The interest-enjoyment subscale is considered to be the self-report measure of intrinsic motivation (7 items, e.g., “I enjoy participating in the NOM-tv exercises very much”). Perceived competence to perform the NOM-tv exercises can be seen as a positive predictor of both self-report and behavioral measures of intrinsic motivation (5 items, e.g., “I am pretty skilled at participating in the NOM-tv exercises”). The effort-importance subscale determined whether respondents thought NOM-tv was important to them and whether they were willing to put effort into participating in the NOM-tv exercises (5 items, e.g., “I put a lot of effort into participating in the NOM-tv exercises”). The pressure-tension subscale is assumed to be a negative predictor of intrinsic motivation (5 items, e.g., “I felt very tense while participating in the NOM-tv exercises”). Perceived choice in performing the NOM-tv exercises is considered a positive predictor of intrinsic motivation (7 items, e.g., “I participated in the NOM-tv exercises because I wanted to”). Finally, the value-usefulness subscale can also be viewed as a positive predictor of intrinsic motivation, since people internalize and become self-regulating with respect to activities that they perceive as useful or valuable for themselves (7 items, e.g., “I believe that participating in the NOM-tv exercises could be beneficial to me”). All items were rated on a 7-point Likert scale, ranging from 1 (*not at all true*) to 7 (*very true*). The pressure-tension subscale was reversed, as high pressure-tension is negatively associated with intrinsic motivation. Negatively formulated items in other subscales were also reversed. Subscale scores were then calculated by averaging across all items within one subscale. Higher scores indicated a more internal, self-regulated type of behavior.

2.2.3. Participation in the NOM-tv Exercises. The outcome measure in the present study, participation in the NOM-tv exercises, was measured by asking how often respondents actively participated in the NOM-tv exercises: “occasionally (0)” or “every time/nearly every time (1)”.

2.3. Data Analysis. Analyses were carried out using SPSS 15.0 software (SPSS inc., Chicago, ILL, USA) in four steps. First, reliability analyses were carried out for all IMI subscales. Internal consistency of the six IMI subscales was generally satisfactory [24], with the following Cronbach’s alphas: interest-enjoyment (α = .78; M = 6.06; SD = 1.36), perceived competence (α = .82; M = 5.14; SD = 1.52), effort-importance (α = .75; M = 6.26; SD = 1.26), pressure-tension (α = .64; M = 1.59; SD = 1.34), perceived choice (α = .67; M = 6.65; SD = 1.03), and value-usefulness (α = .84; M = 6.14; SD = 1.11). The IMI subscales were then correlated with exercise behavior and viewing habits. The third step

Table 1: Background characteristics of the respondents ($N = 1{,}349$).

Gender	Male		16.1%
	Female		83.9%
Age	<55		11.4%
	55–65		39.1%
	65–75		35.6%
	>75		13.9%
		mean (SD)	64.7 (8.7)
BMI	<18,5 (underweight)		0.7%
	18,5–25 (normal/healthy weight)		44.3%
	25–30 (overweight)		39.9%
	>30 (obese)		15.0%
		mean (SD)	26.1 (4.2)
Marital status	Married or living together with partner		62.3%
	Unmarried and never been married		5.4%
	Divorced/living separately		15.8%
	Widow/widower		16.5%
Current occupational status	Working		19.5%
	Housewife/-man		17.5%
	Retired/early retirement		51.0%
	Not occupied/other options		12.1%
Educational level	Low		44.5%
	High		55.5%
Urbanization	Village		47.4%
	Town or city		52.6%
Nationality	Dutch		94.8%
	Other nationality		5.2%
Perceived personal health status	Rating on scale of 1–10	mean (SD)	7.3 (1.2)
Compliance with physical activity guidelines (SQUASH)	Not complying with guidelines		52.3%
	Complying with guidelines		47.7%
Viewing habits	Watching less than weekly		6.1%
	Watching 1-2 times a week		20.3%
	Watching 3-4 times a week		41.0%
	Watching 5–7 times a week		32.5%
Participation in the NOM-tv exercises	Participating occasionally		22.4%
	Participating every time/nearly every time		77.6%

was an independent samples t-test to investigate whether the respondents who reported a low frequency of participation in the NOM-tv exercises had different scores on the six IMI subscales, compliance with the physical activity guidelines, and viewing habits than those who reported a higher frequency of participation in the NOM-tv exercises. Finally, a logistic regression analysis was used to explain participation in the NOM-tv exercises, with the IMI subscales as independent variables, corrected for demographic variables, perceived personal health status, compliance with the physical activity guidelines, and viewing habits.

3. Results

An overview of the respondents' background characteristics is given in Table 1. Women were clearly overrepresented in the viewer population (83.9%). Most of the respondents were between 55 and 75 years old, with a mean age of 64.7 years. More than half of all respondents were overweight/obese. Most people were married or living with a partner, and more than half of all respondents were retired. Slightly more than half of the respondents were highly educated and lived in a town or city. Almost all respondents had Dutch nationality. Respondents were moderately positive about their personal health status, with an average rating of 7.3 (SD 1.2). Furthermore, 47.7% of the respondents complied with the Dutch physical activity guidelines.

Regarding viewing habits, most respondents (41.0%) indicated that they watched NOM-tv 3 or 4 times a week, whereas 32.5% reported watching it 5–7 times a week. One out of four respondents viewed NOM-tv twice a week or less. Approximately three out of four respondents reported participating in NOM-tv every time or nearly every time.

Table 2: Correlation matrix for the six IMI subscales, compliance with the physical activity guidelines, and viewing habits.

	I/E*	PCo*	E/I*	P/T*	PCh*	V/U*	Compliance PA guidelines
I/E*	—						
PCo*	.462	—					
E/I*	.487	.501	—				
P/T*	-.324	−.434	−.432	—			
PCh*	.197	.222	.334	−.417	—		
V/U*	.496	.312	.430	−.314	.224	—	
Compliance PA guidelines*	.059[b]	.178	.064[b]	−.116	.076	−.018[a]	—
Viewing habits	.311	.322	.282	−.184	.009[a]	.268	−.037[a]

Note. *I/E = interest-enjoyment subscale; PCo = perceived competence subscale; E/I = effort-importance subscale; P/T = pressure-tension subscale; PCh = perceived choice subscale; V/U = value-usefulness subscale; compliance PA guidelines = compliance with physical activity guidelines.
Correlations were significant at a level of P <.01 (2-tailed), except for:
(a) not significant,
(b) significant at a level of P <.05.

Table 3: T-test between the six IMI subscales, compliance with the physical activity guidelines, viewing habits and participation in the NOM-tv exercises.

	Participation in the NOM-tv exercises			
	Occasional participants mean (SD)	Frequent participants mean (SD)	T-value	P value
Interest-enjoyment	5.52 (.99)	6.21 (.84)	11.03	<.001
Perceived competence	4.32 (1.17)	5.38 (1.05)	14.16	<.001
Effort-importance	5.61 (1.03)	6.45 (.78)	13.16	<.001
Pressure-tension	2.04 (1.03)	1.46 (.77)	−8.96	<.001
Perceived choice	6.52 (.73)	6.68 (.58)	3.64	<.001
Value-usefulness	5.87 (.92)	6.22 (.78)	5.91	<.001
Compliance with physical activity guidelines	.41 (.49)	.50 (.50)	2.79	.006
Viewing habits	2.49 (.86)	3.15 (.83)	11.72	<.001

Note. Compliance with physical activity guidelines was measured by: non-compliance (0) versus compliance (1); Viewing habits were measured by: watching less than weekly (1), watching 1-2 times a week (2), watching 3-4 times a week (3) and watching 5–7 times a week (4).

Table 2 presents the correlations between the IMI subscales, compliance with the physical activity guidelines, and viewing habits. The correlation coefficients show that there were strong associations between the IMI subscales, in the expected direction. Moreover, there were strong positive correlations between viewing habits and interest-enjoyment, perceived competence, effort-importance and value-usefulness, whereas a negative association was observed between pressure-tension and viewing habits. These correlations indicate that the more intrinsically motivated people are to participate in the NOM-tv exercises, the more likely they are to watch the program.

Occasional participants differed from frequent participants (Table 3), in that frequent participants enjoyed participating more, experienced higher levels of perceived competence and perceived choice, valued the exercises more, and put more effort into the exercises. Those who perceived less tension or pressure more often engaged in the exercises as well. Finally, frequent participants were more active in their daily lives and more frequently watched the program.

Table 4 shows the results of the logistic regression analysis used to determine the predictive value of the IMI subscales for participation in the NOM-tv exercises, corrected for demographic variables, perceived personal health status, compliance with the physical activity guidelines and viewing habits. Model 1 shows that being female, having a lower BMI, having a higher educational level, complying with the physical activity guidelines and more frequent viewing habits were significantly associated with a higher frequency of participation in the NOM-tv exercises. Model 2-adding the IMI subscales to the background characteristics—shows that the IMI subscales of enjoying the exercises more, having a higher level of perceived competence to perform the exercises, being willing to put more effort into the exercises, and attaching less value to NOM-tv were significantly associated with a higher frequency of participation in the NOM-tv exercises. Gender and compliance with the physical activity guidelines did not add significantly to the model that included the IMI subscales, whereas living in a village did not significantly add to Model 1, but did appear as a significant factor in Model 2. A total of 35% of the variance in NOM-tv exercise participation was explained.

4. Discussion

The present study examined the underlying type of motivation among viewers of NOM-tv for participating in the

Table 4: Logistic regression analysis of the IMI subscales on participation in the NOM-tv exercises, corrected for background characteristics.

Independent variables	Model 1		Model 2	
	OR (CI)	*P* value	OR (CI)	*P* value
Gender	1.81 (1.18–2.76)	.006	1.57 (.99–2.50)	ns
Age	1.00 (.98–1.03)	ns	1.02 (1.00–1.04)	ns
BMI	.91 (.88–.95)	<.001	.95 (.91–.99)	.011
Marital status	.89 (.78–1.03)	ns	.92 (.79–1.07)	ns
Occupational status	.98 (.88–1.09)	ns	.96 (.86–1.07)	ns
Educational level	1.41 (1.03–1.94)	.034	1.62 (1.14–2.29)	.007
Urbanization	.79 (.58–1.08)	ns	.71 (.50–.99)	.044
Nationality	.71 (.37–1.36)	ns	.55 (.27–1.09)	ns
Perceived personal health status	1.12 (.99–1.27)	ns	.99 (.86–1.14)	ns
Compliance with physical activity guidelines	1.49 (1.09–2.05)	.014	1.20 (.85–1.70)	ns
Viewing habits	2.47 (2.06–2.95)	<.001	1.86 (1.51–2.28)	<.001
Interest-enjoyment			1.38 (1.11–1.70)	.003
Perceived competence			1.55 (1.29–1.86)	<.001
Effort-importance			1.65 (1.32–2.07)	<.001
Pressure-tension			.84 (.68–1.05)	ns
Perceived choice			.78 (.58–1.06)	ns
Value-usefulness			.78 (.62–.98)	.034
Nagelkerke's R^2	.21		.35	

Note. ns = not significant.

program's exercises, in order to assess whether NOM-tv promotes more autonomous or more controlling participation motives. Useful information can be deduced from this study about people's motives to take part in exercises presented via television, a channel which typically evokes sedentary behavior.

Whereas Martin and Sinden [36] reported a lack of theory-based systematic research examining predictors of exercise adherence, the results of the current theory-based study show that enjoyment, higher perceived competence, and higher willingness to put effort into the NOM-tv exercises—thus showing higher levels of intrinsic motivation—were generally associated with more frequent participation in the exercises. Based on the theoretical ground of NOM-tv, we expected a positive relationship between perceived competence and participation in NOM-tv. Based on the Self-Determination Theory, we expected that respondents who perceived more autonomous motives to engage in the NOM-tv exercises would also participate more often in the NOM-tv exercises. We can conclude that both hypotheses were confirmed.

The present study also revealed the characteristics of frequent participants in the NOM-tv exercises versus occasional participants. The results showed that frequent viewers were also more likely to participate, as were people who were more active in their daily lives. Other subgroups of our study population more likely to participate in the NOM-tv exercises included people with a lower BMI, people living in a village, and people with a higher educational level. Comparing these results to the findings in the study of Hopman-Rock et al. [15], participants in both studies were mainly older women. As NOM-tv was designed for adults (mainly targeting people aged 55 and over), on the one hand it can be concluded that NOM-tv probably reaches its target audience. On the other hand, the present study revealed that more frequent participants were people who were more active in their daily lives, had a lower BMI and a higher educational level, whereas lower educated people with lower activity levels and a higher BMI could be viewed as those who are most in need of a physical activity intervention, and therefore, the program should also aim to get these people started. Due to the cross-sectional design, it can however not be concluded whether this higher activity level of frequent participants was reinforced by participation in the NOM-tv exercises or that NOM-tv is particularly appealing for individuals who already tend to be active by themselves. Regardless the result that higher educated, more active respondents with normal weight participated more in the NOM-tv exercises, people who are more in need of reducing sedentary behavior—that is, people with lower educational levels and higher BMI—were also a substantial part of our sample. Therefore, it can be concluded that those people were also attracted to viewing; however, they could use some more (autonomy-supportive) stimulation to also participate in the NOM-tv exercises.

Given that the independent samples t-test showed that frequent participants in the NOM-tv exercises valued the exercises more than occasional participants, it was remarkable that attaching value to NOM-tv seemed to predict less participation in the multivariate analysis. Apparently, the constructs of interest-enjoyment, perceived competence and effort-importance were such influential predictors of participation that the predictive value of the value-usefulness subscale was overridden. The percentage of variance explained by the two logistic regression models was reasonably high, and the internal consistency of the six IMI subscales was generally satisfactory.

The predictive value of the interest-enjoyment, perceived competence, and effort-importance subscales on self-regulation of exercise behavior has also been found in previous studies [26, 37–39]. With regard to participating in a television exercise program, our study confirmed the importance of enjoying physical activity, feeling competent to perform the activity and being willing to put effort into the activity. Since intrinsic motivation is regarded as the most important predictor of sustained physical activity [19], it seems plausible that participation in the exercises will be sustained over time. However, the cross-sectional design of the current study precluded definitive conclusions on this issue. The use of self-report measures was another limitation in this study, which might have led to inaccurate recall and social desirability bias. Sallis and Saelens [40] state that people tend to overestimate their physical activity level in self-report measures, which in the present study might have led to overreporting of respondents' actual physical activity levels. Besides, NOM-tv comprises five physical activity blocks. By the measures used in the present study, it could not be indicated whether or not the respondents engaged in all five blocks each time.

It can be recommended to develop more research studies regarding motivational mechanisms influencing exercise engagement and reducing sedentary behavior in the future. Since Self-Determination Theory-based studies have been predominantly cross-sectional [25], we would advise to include a pre- and postintervention measurement.

With regard to developing future interventions to stimulate people to reduce sedentary behaviors, we would recommend that mass media interventions encourage people's intrinsic orientations towards physical activity in an autonomy-supportive way, in which pressure to engage in the specific physical activity is minimized and people are encouraged to initiate actions based on their personal goals and values [19]. Furthermore, it can be recommended to promote the intrinsic fun and excitement of exercise, which—like in NOM-tv—could be done by selecting enthusiastic instructors and making use of music, either as a beat to follow or just an enjoyable and motivating background [20, 41]. Besides, it is recommended to support participants' perceived competence in executing the exercises, for example, by encouraging active experimentation, providing good instructions and guidance, and promoting confidence (e.g., through modeling) [27, 41].

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Review Article

Intervening to Reduce Sedentary Behaviors and Childhood Obesity among School-Age Youth: A Systematic Review of Randomized Trials

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Objective. To assess the effectiveness of interventions that focus on reducing sedentary behavior (SB) among school-age youth and to identify elements associated with interventions' potential for translation into practice settings. *Methods*. A comprehensive literature search was conducted using 4 databases for peer-reviewed studies published between 1980 and April 2011. Randomized trials, which lasted at least 12 weeks, aimed at decreasing SB among children aged 6 to 19 years were identified. *Results*. Twelve studies were included; 3 focused only on SB, 1 focused on physical activity (PA), 6 were combined SB and PA interventions, and 2 studies targeted SB, PA, and diet. The majority of the studies were conducted in a school setting, while others were conducted in such settings as clinics, community centers, and libraries. *Conclusions*. Overall, interventions that focused on decreasing SB were associated with reduction in time spent on SB and/or improvements in anthropometric measurements related to childhood obesity. Several of the studies did consider elements related to the intervention's potential for translation into practice settings.

1. Introduction

Childhood obesity has long been recognized as a worldwide growing health concern [1–3]. In the past 2 decades, rates of obesity in the US rose among children aged 6 to 11 years from 11.3% to 19.6%, as well as from 10.5% to 18.1% among adolescents aged 12 to 19 years [4, 5]. Similarly, Great Britain has experienced a threefold increase of overweight in children between 1984 and 2002 [6], and prevalence of obesity among younger children in China has increased from 1.5% to 12.6% between 1989 and 1997 [7]. Early consequences of childhood obesity include asthma, hypertension, and early-onset diabetes mellitus [3]. In addition, childhood obesity has been shown to follow into adulthood [8–11] and may lead to cardiovascular disease, cancer, and an increased chance of mortality after the age of 30 years [12, 13].

A majority of previous studies addressing this epidemic have revolved around modifying dietary intake [14, 15] and physical activity (PA) [16–18]. However, sedentary behavior (SB) appears to be a lifestyle behavior that is increasingly contributing to the prevalence of childhood obesity [19] as research has shown that obese children are more sedentary than their nonobese counterparts [20]. Sedentary behavior largely consists of media use; however, other behaviors that do not expend significant energy, such as attending classes or playing a musical instrument, have been explored as SB [21–23]. It is estimated that children spend approximately one-third of their waking hours using media, which includes watching TV/videos, playing video games, and personal computing [24]. These SB may in turn displace PA, decrease metabolic rate, and/or serve as a conditioned stimulus for eating [25].

Lifestyle interventions aimed at reducing SB have potential to make an impact; however, limited knowledge exists as to the effectiveness of such interventions. In addition, aspects related to an intervention's potential for translation to practice are important to consider for such a significant public health issue as childhood obesity. The main objective of this paper is to assess the effectiveness of interventions that focus on reducing SB among school-age youth. A second objective is to identify the elements of the identified interventions related to potential translation to practice settings, such as cost or health disparity implications and sustainability of intervention impact.

2. Methods

2.1. Literature Search. Four databases (Medline, PubMed, PsychInfo, Cochrane Library) were searched for the relevant studies published between 1980 and April 2011. For this paper, such keywords as "sedentary behavior," "sedentary lifestyle," "physical inactivity," "television," "video games," "children," "adolescents," and "intervention" were used alone and/or in combination. Relevant references were extracted and examined, compiling the list in the form of titles and abstracts of the selected studies.

2.2. Inclusion Criteria. Identified studies included those that used an intervention aimed at decreasing SB, separately or in combination with body mass index (BMI) or other anthropometric changes, such as waist circumference or triceps skinfold thickness, among children and adolescents, 6 to 19 years of age. We focused on studies that described randomized trials, conducted in the community, school, home, or clinic setting, which lasted at least 12 weeks, and included such strategies as educational, health promotion, behavioral therapy, counseling, or management strategies at the individual and family levels. Studies whose primary goal was to measure changes in PA levels were included if the change in SB was also measured and specified in the results. Sedentary behavior was defined as media-related behavior (time spent watching TV/videotapes, playing video games), breaks from activity, and activities that do not significantly influence the energy expenditure occurring at rest.

2.3. Exclusion Criteria. Searches were conducted only in the English language. Studies based within a controlled laboratory setting were not considered relevant or generalizable, and therefore, not included in the analysis.

2.4. Selection Process. The results of the preliminary search were reviewed; relevant titles with abstracts were then retrieved. Bibliographies of some systematic review papers were reviewed to identify additional studies. Full articles of relevant abstracts were retrieved for further review. Two authors independently assessed retrieved studies for inclusion based upon the criteria listed above. Any inconsistencies were resolved by discussions with the other author. Summary tables were composed of the selected studies. The tables included study design, setting in which it was conducted, theory, characteristics of the participants, duration of the intervention and followup, brief description of intervention, definition of control group, measures of SB and additional outcomes, key findings, demographic disparities information, and limitations.

3. Results

A total of 2.939 abstracts were identified through the initial search process. Upon review, 31 full papers were retrieved for further review by two investigators. Of those 31 papers, 12 studies met the inclusion criteria. Figure 1 outlines the flow of the search process and the number of articles that were identified at each stage of the process.

Three studies [22, 23, 26] focused only on SB, 1 study was a PA intervention [27], 6 studies [20, 21, 28–31] were combined SB and PA interventions, and 2 studies [32, 33] targeted SB, PA, and diet. Of the 12 studies, 8 were conducted in the US, 3 in Europe (including the UK, France, and the Netherlands), and 1 in Australia. The majority (7 out of 12) of the studies were conducted in a school setting, while 2 were conducted in a clinic, 1 in community centers, 1 conducted in both community centers and schools, and 1 other was carried out in convenient locations, which included clinics, libraries, and schools.

Table 1 summarizes the study design and characteristics, while Table 2 summarizes the outcome measurements focused on SB and anthropometrics and also key findings of each study. The definition of SB varied across the studies. Listed here are all the forms of SB that were measured: time spent watching TV and videotapes, playing video games, doing homework, reading, listening to music, using a computer, playing a musical instrument, doing artwork or crafts, talking with parents, playing quiet games indoors, and attending classes or club meetings. Due to the diversity in study design, study duration, setting, population, and measurement outcomes of the interventions, a quantitative synthesis of the evidence was not possible. Therefore, a qualitative assessment of the current evidence stratified by targeted behaviors is presented.

3.1. Sedentary Behavior Studies. Three studies [22, 23, 26] focused on reducing SB in school-aged children. Escobar-Chaves et al. [26] aimed to reduce TV and other media consumption in families with children of ages 6 to 9 years in Houston, Tex, US. One hundred one families were randomized to either the 6-month intervention, which included a 2-hour workshop and 6 bimonthly newsletters, or a control group. The parents and children also worked together to develop a plan in which alternative activities could be done by the child and family in place of SB. At 6-month followup, there was a trend toward reducing media consumption in the intervention group; however, these results were not statistically significant. The intervention did find a positive impact on proxy behaviors hypothesized to lead to media use reductions, which are also recommended by the American Academy of Pediatrics, such as not having a TV in the child's bedroom.

Robinson [22] randomly assigned 3rd and 4th graders in 1 of 2 public elementary schools in San Jose, Calif, US to receive an 18-lesson, 6-month classroom curriculum to reduce TV, videotape, and video game use. The curriculum, which was taught by the regular classroom teachers, included self-monitoring and self-reporting of media use, followed by a TV turnoff, in which children were challenged not to use

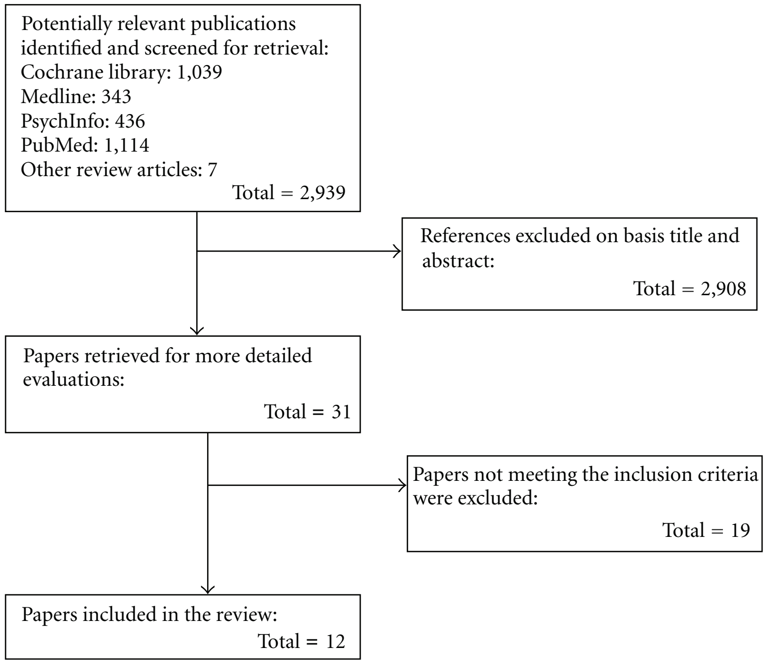

Figure 1: Flow chart of the search process.

media for 10 days. After the turnoff challenge, the children were encouraged to follow a 7-hour/week budget of media use. Each household also received an electronic TV time manager, which monitored and bugeted TV/video use for each household member. Newsletters designed to motivate parents to help their children maintain their TV watching limits were also distributed. At the end of the intervention, children in the intervention group had decreases in multiple anthropometric measures, which included BMI, triceps skinfold thickness, waist circumference, and waist to hip ratio ($P < 0.002$), compared to the control group. In addition, reported TV use was lower in the intervention group (8.80 versus 14.46 hours/week; $P < 0.001$); however, no significant changes were reported in video tape and video game use.

Another study conducted by Robinson and borzekowski [23] consisted of a randomized controlled trial among 3rd and 4th graders in San Jose, Calif, US in 2 public elementary schools ($n = 181$). The intervention was an 18-lesson classroom curriculum focused on reducing screen media exposure. Components of the intervention included children becoming aware of the role TV, videotapes, and video games play in their lives, a TV turnoff in which children attempted to watch no TV/videotapes or play video games for 10 days, children learning how to budget their media use, and participants helping their peers at another school to reduce their media use. Newsletters were also distributed to the parents. Children in the intervention school significantly decreased their weekday TV viewing (1.14 versus 1.96 hours/day; $P < 0.001$) and weekday (0.19 versus 0.52 hours/day; $P < 0.05$) and Saturday video game playing (0.31 versus 0.9 hours/day; $P < 0.05$) compared to controls. Greater effects were found among boys ($P = 0.05$) and more adult-supervised children ($P = 0.03$).

3.2. Physical Activity Study. One study that focused solely on PA in school-aged children was identified. Slootmaker et al. [27] randomized 87 13-to-17 year olds in Amsterdam, The Netherlands to receive either a single brochure with PA recommendations or an accelerometer and access to web-based tailored PA advice for 3 months. When a user logged into the website and uploaded his/her PA score, the website provided individualized PA feedback based on the current PA score and personally adapted suggestions to promote daily PA. At 5-month followup, time spent doing SB was significantly reduced in boys (−1,801 minutes/week; $P = 0.04$). No SB changes were observed in girls.

3.3. Sedentary Behavior and Physical Activity Studies. Six studies [20, 21, 28–31] that targeted both SB and PA were identified. Epstein et al. [21] randomized obese children of ages 8 to 12 years from 61 families to 1 of 3 treatment groups: (1) increasing exercise (Exercise), (2) decreasing SB (Sedentary), or (3) both increasing exercise and decreasing SB (Combined). All groups received similar information (distributed through manuals) about the benefits of increased PA and the negative effects of SB; however, the groups differed in the types of activities that were reinforced. The Sedentary group was reinforced for decreasing the amount of time they engaged in certain SB; these SBs included media use, imaginative play, talking on the phone, and playing board games. Participants in the Exercise group were reinforced for increasing PA, while those in the Combined group

Table 1: Description of interventions to reduce sedentary behavior in youth.

Reference	Design	Theory	Setting	Study duration	Participants	Intervention	Control
				Sedentary behavior studies			
Escobar-Chaves et al. [26]	RCT	No specific theory reported	Convenient locations (clinics, public libraries, and schools); US	I: 6 months F/U: 6 months	N (C) = 101 N (I) = 101 Mean age (y): Parents: 40 ± 7.6 Children: 8.2 ± 0.8 Sex: Parents: 88.6% female Children: 51.5% male Race: Parents: 43.6% white Children: not reported	2-hour workshop and 6 bimonthly newsletters to reduce media consumption	No detail reported
Robinson [22]	RCT	Social cognitive model	2 public elementary schools; US	I: 6 months F/U: No detail reported	N (C) = 120 N (I) = 105 Mean age (y): C: 8.9 ± 0.6 I: 8.9 ± 0.7 Sex: C: 55.4% male I: 52.8% male Race: C: 80.6% white I: 77.2% white	18-lesson classroom curriculum to reduce screen time; 14 parent newsletters	No treatment control
Robinson and Borzekowski [23]	RCT	Social cognitive theory	2 public elementary schools; US	I: 6 months F/U: No detail reported	N (C) = 100 N (I) = 92 Mean age (y): 8.95 ± 0.64 Sex: 46% female Race: not reported	18 in-class lessons; TV turnoff challenge followed by encouragement to budget TV time to 7 hrs/week; parent newsletters	No detail reported
				Physical activity studies			
Slootmaker et al. [27]	RCT	No detail reported	5 secondary schools; The Netherlands	I: 3 months F/U: 5 months	N (C) = 41 N (I) = 38 Mean age (y): C: Boys: 14.8 ± 1.4 Girls: 15.0 ± 1.2 I: Boys: 15.3 ± 1.1 Girls: 15.4 ± 1.1 Sex: 63% female Race: not reported	Accelerometer; web-based, tailored PA advice to increase PA and decrease SB	Brochure with recommendations for PA

Table 1: Continued.

Reference	Design	Theory	Setting	Study duration	Participants	Intervention	Control
Sedentary behavior and physical activity studies							
Epstein et al. [21]	Randomized trial	No detail reported	Clinic; US	I: 6 months F/U: 6 months	N = 61 families Mean age (y): Child: 10.1 Sex: 73% female Race: 96% white	Weekly family-based treatment meetings focused on PA and SB; 3 intervention groups received reinforcement for either reducing sedentary activities, increasing PA, or combination	Not applicable
Epstein et al. [20]	Randomized Trial	No detail reported	Clinic; US	I: 6 months F/U: 6 months	N = 56 Mean age (y): Children: 10.4 ± 1.2 Sex: 51.8% male Race: 94.6% white	Family-based treatment meetings focused on reinforcing increasing PA or combination of reducing SB and increasing PA	Not applicable
Jones et al. [28]	RCT	Social cognitive theory; Transtheoretical model	Middle schools; US	I: 1.5 academic years F/U: no detail reported	N (C) = 371 N (I) = 347 Mean age (y): 11.6 ± 0.4 Sex: 100% female Race: 72% white	16-session health curriculum; PE program and school food service component with emphasis on calcium-rich foods	Usual health program
Robinson et al. [29]	RCT	Social cognitive model	Low-income neighborhood community centers; US	I: 12 weeks F/U: no detail reported	N (C) = 33 N (I) = 28 Mean age (y): C: 9.5 ± 0.9 I: 9.5 ± 0.8 Sex: 100% female Race: 100% AA	60 after-school dance classes plus 5 home lessons to reduce TV time	Newsletters and health education lectures
Salmon et al. [30]	RCT	Social cognitive theory; Behavioral choice theory	Government schools in low socioeconomic areas; Australia	I: 1 academic year F/U: 12 months	N = 306 Mean age (m): 10.8 ± 5 Sex: 51% female Race: not reported	19 in-class lessons promoting PA and decreasing SB; 3 intervention groups received either behavior modification of PA and SB, movement skill games or combination of both	Usual curriculum
Simon et al. [31]	RCT	No detail reported	Public middle schools; France	I: 4 school years F/U: no detail reported	N (C)= 479 N (I) = 475 Mean age (y): C: 11.7 ± 0.7 I: 11.6 ± 0.6 Sex: C: 52% male I: 54% female	Multilevel program focused on changing knowledge/attitudes towards PA and SB; providing environmental opportunities for PA	Usual health and PE curriculum

Table 1: Continued.

Reference	Design	Theory	Setting	Study duration	Participants	Intervention	Control
Sedentary behavior, physical activity and diet studies							
Gortmaker et al. [32]	RCT	Behavioral choice theory; Social cognitive theory	10 public schools; US	I: 2 academic years F/U: No detail reported	*N* (5 C schools) = 654 *N* (6 I schools) = 641 Mean age (y): 11.7 ± 0.7 Sex: 48% female Race: C: 69% white I: 63% white	*Planet Health* curriculum: 32 lessons on reducing TV time, increasing PA, decreasing high-fat food intake, and increasing F/V intake	Regular school curriculum
Sacher et al. [33]	RCT	Social cognitive theory	Community centers and schools, UK	I: 6 months F/U: 6 months	*N* (C)= 56 *N* (I) = 60 Mean age (y): C: 10.2 ± 1.3 I: 10.3 ± 1.3 Sex: C: 45% females I: 63% females Race: C: 50% white I: 50% white	18 2-hour group educational and PA sessions, followed by 12-week family swimming pass	6-month delayed intervention

RCT, randomized controlled trial; US, United States; I, intervention; F/U, duration of followup after intervention completed; C, control; y, year; TV, television; hrs, hours; PA, physical activity; SB, sedentary behavior; PE, physical education; AA, African American; F/V, fruits and vegetables.
Note: N represented at baseline.

Table 2: Evaluation of interventions to reduce sedentary behavior in youth.

Reference	Outcome: Sedentary behavior	Outcome: Anthropometric	Outcome: Other	Key findings	Demographic disparities	Limitations
Sedentary behavior studies						
Escobar-Chaves et al. [26]	Self-reported household media environment and media use by children	No detail reported	No detail reported	At 6-month F/U, intervention group was less likely to report TV being ON when nobody was watching (AOR = 0.23, $P < 0.05$). A trend towards reducing media consumption was also observed in the intervention group.	No detail reported	Self-reported behaviors; small sample size
Robinson [22]	Self-reported media use (TV, video tape,and video game) and other SB (e.g., using computer, doing homework, and reading)	BMI; waist/hip circumference; triceps skinfold thickness	Self-reported PA, cardiorespiratory fitness, and dietary behaviors	Compared to controls, intervention group had significant decreases in anthropometric measures, such as BMI (ADJ DIFF = −0.45 kg/m2; $P = 0.002$) and triceps skinfold thickness (ADJ DIFF= −1.47 mm; $P = 0.002$). Intervention group reported reduced TV ($P < 0.001$) and video game ($P = 0.01$) use compared to controls.	No detail reported	Small sample size; snacking while watching TV assessed as a proportion
Robinson and Borzekowski [23]	Self-reported household media environment, media use, and other activities (e.g., using TV, video, computer, doing homework, and talking with parents)	No detail reported	No detail reported	Compared to controls, intervention group significantly reduced weekday TV viewing (95% CI −1.22 to −0.35; $P < .001$) and weekday (95% CI −0.48 to −0.01; $P < .05$) and Saturday (95% CI −1.04 to −0.01; $P < .05$) video game playing.	Greater effects were observed among boys compared to girls	Self-reported behaviors; and intervention conducted in two schools
Physical activity studies						
Slootmaker et al. [27]	Self-reported time spent sedentary (TV, computer)	BMI; waist/hip circumference; skinfold thickness (biceps, triceps, subscapular, and suprailiac)	Self-reported PA; determinants of PA; aerobic fitness	Boys in the intervention group showed significant reduction in sedentary time (−1801 min/week, −3545 to −57, 95% CI; $P = 0.04$), after 5-month F/U.	SB change was maintained in boys at 5-month F/U	Self-reported behaviors; insufficient power due to high dropout rate and separation of analyses

Table 2: Continued.

Reference	Outcome			Key findings	Demographic disparities	Limitations
	Sedentary behavior	Anthropometric	Other			
Sedentary behavior and physical activity studies						
Epstein et al. [21]	Self-reported sedentary activities (e.g., TV, computer use, and talking on phone)	Percent over weight; PBF; waist/hip circumferences	Physical work capacity; activity preference; compliance and choice	At 6-month F/U, the Sedentary group had greater decrease in percentage overweight than did the Combined and Exercise groups (-18.7 versus -10.3 and -8.7; $P < 0.05$) and greater decrease in PBF (-4.7 versus -1.3; $P < 0.05$).	No detail reported	Self-report; lack of blinding
Epstein et al. [20]	Self-reported SB (TV viewing)	BMI; percent overweight	Psychological measures, adherence to diet, and PA questionnaire	Boys showed larger decrease in percentage overweight than girls in Combined ($F = 8.98$; $P < 0.001$) and Increased activity ($F = 4.45$; $P < 0.025$) groups. At 6-month F/U, boys showed BMI decrease of -1.76 ± 1.86 in Combined group and 0.65 ± 1.37 in Increased activity group. Girls showed BMI increase of 1.00 ± 1.73 for Combined group and decrease of 0.27 ± 1.37 in Increased activity group.	Treatment was more effective on boys, and they had better treatment adherence compared to girls	No detail reported
Jones et al. [28]	Self- reported sedentary activities (TV, video, computer/video games)	No detail reported	Self-reported calcium intake; PA; osteoporosis knowledge	Relative to control schools, the intervention significantly reduced duration of student daily TV/video watching (mean difference between I and C = 12.11 min; 95% CI, 11.74 to 12.48; $P = 0.05$) and total daily sedentary activity (mean difference between I and C = 16.99 min; 95% CI, 16.59 to 17.50; $P = 0.04$).	No detail reported	Evaluation at two points only; a small number of groups randomized to treatment conditions; self-reported; limited information on covariates

Table 2: Continued.

Reference	Outcome			Key findings	Demographic disparities	Limitations
	Sedentary behavior	Anthropometric	Other			
Robinson et al. [29]	Self-reported media use (TV, videotapes, and video games) and eating with TV on	BMI; waist circumference	Insulin and glucose levels; lipid levels	Intervention group showed trends towards BMI decrease (ADJ DIFF = −0.32 kg/m2; 95% CI, −0.11 to 0.12), waist circumference decrease (ADJ DIFF = −0.63 cm; 95% CI, −1.92 to 0.67), and reduced TV, videotape, and video game use (ADJ DIFF = −4.96 hrs/week; 95% CI, −11.41 to 1.49).	Type 2 diabetes disproportionately affects girls and AAs; some of greatest increases in childhood obesity among AA girls	Self-reported behaviors
Salmon et al. [30]	Self-reported screen behaviors (TV, computer, and electronic games)	BMI	PA accelerometer; self-reported enjoyment of PA; FMS; body image; food intake	Significant intervention effect on BM in BM/FMS group compared to controls, maintained at 6- and 12-month followup (AOR = 0.38; $P < 0.05$). BM group reported highest levels of TV viewing compared to other groups ($P < 0.05$).	No findings related to anthropometric measures or SB	Self-report; Thepubertal staging not assessed; sample size underpowered; randomization by class
Simon et al. [31]	Self-reported SB (e.g., TV, computer)	BMI; PBF	Self-reported PA; PA self-efficacy, social support, and intention	In the intervention group, high SB (>3 hrs/day) was reduced in girls (OR = 0.54; 95% CI, 0.38 to 0.77) and boys (OR = 0.52; 95% CI 0.35 to 0.76).	No detail reported	Self-reported behavior; lack of time to assess intervention effect on health outcomes
Sedentary behavior, physical activity and diet studies						
Gortmaker et al. [32]	Self-reported media use (TV and video viewing)	BMI; triceps skinfold thickness	Self-reported PA and dietary intake	Intervention reduced TV hrs among girls and boys ($P < 0.001$). In intervention group, obesity prevalence was significantly reduced in girls compared to controls (23.6% to 20.3%), and each hr of TV reduction predicted reduced obesity prevalence (OR = 0.85; 95% CI, 0.75 to 0.97; $P = 0.02$).	Largest intervention effects observed among AA girls with obesity prevalence significantly reduced. No significant differences observed among boys or Hispanic girls.	Self-reported behavior; participation rate of student at baseline was 65% due to required written consent

Table 2: Continued.

Reference	Outcome: Sedentary behavior	Outcome: Anthropometric	Outcome: Other	Key findings	Demographic disparities	Limitations
Sacher et al. [33]	Self-reported sedentary activities (e.g., TV, computer)	BMI; PBF; waist circumference	Cardiovascular fitness; self-esteem; self-reported PA	At 6-month F/U, intervention group participants had reduced waist circumference z-score (-0.47; $P < 0.0001$) and BMI z-score (-0.23; < 0.0001) compared to controls	No detail reported	Lack of blinding; selective dropout; short followup

F/U, duration of follow-up after intervention completed; TV, television; AOR, adjusted odds ratio; SB, sedentary behavior; PA, physical activity; BMI, body mass index; ADJ DIFF, adjusted difference; CI, confidence interval; min, minutes; PBF, percent body fat; hrs, hours; AA, African American; FMS, fundamental movement skills; BM, behavioural modification; OR, odds ratio.

were reinforced for both decreasing SB and increasing PA. Weekly treatment meetings were also conducted for both the parent and child. At 6-month followup, the Sedentary group had greater decrease in percentage overweight than did the Exercise or Combined groups (−18.7 versus −10.3 versus −8.7; $P = 0.026$) and greater decrease in percentage of body fat (−4.7 versus −1.3; $P = 0.037$).

Another study by Epstein et al. 2001 [20] randomly assigned 67 families with an obese child between ages of 8 to 12 years to 1 of 2 treatment groups: (1) increasing PA (Increase) or (2) reducing SB and increasing PA (Combined). The treatment program consisted of 16 weekly meetings, followed by 2 biweekly meetings and 2 monthly meetings during a 6-month intensive program. At 6-month followup, boys showed significantly better percentage of overweight changes in the Combined group than girls (−15.8% versus −1.0%; $P < 0.001$), with no significant differences in the Increase group for boys or girls (−9.3% versus −7.6%). Boys also adhered to the treatment better than girls ($P < 0.01$).

Jones et al. [28] recruited 12 middle schools in central Texas to participate in a 1.5-year randomized clinical trial focused on improving bone health mainly through promoting the increase of PA. A total of 718 6th grade girls participated in the intervention, which consisted of a 16-session health curriculum to promote increased weight-bearing PA and consumption of calcium-rich foods. A physical education component was also included, which consisted of high-impact activities. Relative to the girls in the control group, the intervention group significantly reduced daily TV and video minutes (−12.11 minutes/day; $P = 0.05$). Total daily minutes of sedentary activity were significantly lower for intervention students relative to controls (mean difference between groups = −17 minutes; $P = 0.04$).

Robinson et al. [29] conducted a randomized controlled trial with 61 8-to-10-year-old African-American (AA) girls and their parents. The 12-week intervention consisted of after-school dance classes and a 5-lesson family-based intervention delivered in participants' homes to reduce media use. At followup, the girls in the intervention group had trends towards lower BMI (adjusted difference = $-0.32\,\text{kg/m}^2$; 95% CI −0.77 to 0.12) and waist circumference (adjusted difference = −0.63 cm; 95% CI −1.92 to 0.67) and reduced TV, videotape, and video game use (adjusted difference = −4.96 hours/week; 95% CI −11.41 to 1.49).

Salmon et al. [30] randomized, by class, 311 children from 3 government schools in low socioeconomic areas of Melbourne, Australia into one of four conditions: (1) behavioral modification (BM); (2) fundamental movement skills (FMS); (3) combined BM and FMS (BM/FMS); (4) control (usual curriculum). Each of the intervention conditions consisted of 19 lessons promoting PA and decreasing SB. The BM lessons were delivered in the classroom, while the FMS lessons were delivered in PA facilities, which focused on teaching participants physical skills while emphasizing enjoyment and fun. The combined group received both the BM and FMS lessons. There was a significant intervention effect from baseline to postintervention on BMI in the BM/FMS group compared to the control group ($-1.88\,\text{kg/m}^2$; $P < 0.01$), which was maintained at 6- and 12-month followup ($-1.53\,\text{kg/m}^2$; $P < 0.05$). The BM group reported highest levels of TV viewing compared to the other groups (239.9 minutes/week; $P < 0.05$).

Simon et al. [31] conducted a 4-year randomized controlled trial with a cohort of 954 middle-school adolescents in eastern France. The multilevel intervention focused on influencing intrapersonal, social, and environmental determinants of PA and SB through informational sessions, social support by parents, peers, teachers, and PA instructors and by providing environmental conditions for PA to encourage students to apply the knowledge and skills they learned. The study is currently on going; thus, data reported here were collected 6 months into the intervention. After 6 months of the intervention, high SB (<3 hours/day) was reduced in both girls and boys (OR = 0.54 and 0.52; $P < 0.001$) in the intervention group compared to the control.

3.4. Sedentary Behavior, Physical Activity, and Diet Studies. Two studies [32, 33] focused on modifying SB, PA, and diet. Gortmaker et al. [32] randomized 5 out of 10 middle schools in Massachusetts to receive an interdisciplinary intervention over the course of 2 school years. The intervention, *Planet Health*, was included in the existing school curriculum of 4 subjects and physical education classes. The sessions focused on decreasing TV viewing, decreasing consumption of high-fat foods, increasing fruit and vegetable intake, and increasing moderate to vigorous PA. Over the 2-year intervention period, obesity prevalence among girls in the intervention schools decreased compared to controls (OR = 0.47; $P = 0.03$), while no differences were observed in boys. The number of hours of TV/video use was reduced in both boys and girls in the intervention group compared to the control group (adjusted difference between groups for boys and girls = −0.40 and −0.58 hours/day; $P < 0.001$).

Sacher et al. [33] recruited 116 obese children in the UK to be randomly assigned to receive the Mind, Exercise, Nutrition, Do it (MEND) program, a multicomponent community-based intervention. This intervention consisted of 18 2-hour group educational and PA sessions held twice weekly in sports centers and schools, in which both parents and children attended. These sessions were followed by a 12-week free family swimming pass. At 6 months, participants in the intervention group had a reduced waist circumference z-score (−0.37; $P < 0.0001$) and BMI z-score (−0.24; $P < 0.0001$) compared to controls. Significant differences in SB were observed between the intervention and control groups (15.9 versus 21.7 hours/week; $P = 0.01$). The significant decreases in waist circumference and BMI in the intervention group were sustained up to 9 months after participants completed the educational and PA sessions.

4. Discussion

Overall, interventions that focused on decreasing SB, whether alone or in combination with other strategies, such as increasing PA and improving diet, were associated with reduction in time spent on SB and/or improvements in anthropometric measurements related to childhood obesity.

4.1. Study Design. While the results of the majority of the studies were positive, it is not possible to make any conclusions as to the degree of impact each strategy had on the outcomes due to the variability in study design and outcome measurements. There were only 3 studies [22, 23, 26] that focused solely on the reduction of SB, and only 1 of those studies [22] collected anthropometric measures. The other 9 studies combined other strategies, such as exercise and healthy eating. Similar results in relation to anthropometric measures and SB were observed in these studies compared to the studies solely focused on reducing SB.

Another aspect of the study designs that made it challenging to interpret any further than a qualitative summary is the variation in how SB was defined. Some studies examined SB as only media use, while others collected additional measurements, which included behaviors such as talking with parents, playing quiet indoor games, and attending clubs, in addition to media use [21–23]. More consistent measures of different types of SB across studies would assist in determining their relative impact on childhood obesity.

The intensity and dose of the interventions received by participants also varied between interventions. The duration of study periods ranged from 12 weeks to 4 academic years. In addition, some interventions consisted of a workshop and newsletters, while other interventions consisted of multiple lessons and face-to-face encounters with the participants across similar time periods.

Another challenge when assessing impact, particularly when considering potential for translation into practice, was the limited measures of long-term sustainability of the interventions impact. Only 5 out of the 12 identified studies incorporated postintervention follow-up measures [20, 21, 26, 27, 30, 33], which ranged from 5 to 12 months. Overall, a positive long-term impact was observed in either behavioral or anthropometric outcomes in those 5 studies [20, 21, 26, 27, 30, 33]. However, this highlights the challenges in interpreting impact of the interventions and their potential for translation into real-world settings.

4.2. Common Components. One intervention component that appeared to be repeated in several of the designs was the involvement of family. Whether it was for a clinic-based treatment for obese children or promoting positive behaviors to prevent childhood obesity, parents were engaged to varying degrees. In some interventions, the parents were mailed newsletters to reiterate health messages that were presented to children in school [22, 23], while other interventions included having the parent attend workshops/meetings with their children and share in planning healthy events [20, 21, 26, 29, 31, 33]. In one study [23], children who had greater adult supervision were more likely to respond better to the intervention than less supervised children. These study designs and results highlight the importance of having a supportive family environment to promote the positive behaviors that are being targeted.

Another component that was repeated throughout many of the intervention designs was that the children were provided with tangible ideas and appealing alternatives to sedentary activities, and some had the opportunity to choose how to allocate their time [21, 26, 29–31]. When children are provided choice among alternative activities, they may perceive increased control over their activity options, so the reduction in SB observed in the studies could be partly explained by the provision of suggestions, ideas, and options for students.

4.3. Demographic Disparities. Four of the studies [20, 23, 27, 32] reported differential effects of the intervention between genders while measuring SB outcomes or anthropometric changes. The impact was inconsistent across the studies. The gender differences were observed in both a family-based weight control treatment [20] and school-based interventions to prevent obesity [20, 23, 27, 32] targeting a range of ages. Two of the studies [23, 27] observed a greater effect on boys' SB, while the Epstein et al. [20] study resulted in greater changes in % overweight in boys compared to girls. On the other hand, the Gortmaker et al. [32] study observed BMI changes in girls, but not boys.

There is no clear explanation as to the differential effects by gender and also why the results were inconsistent across intervention, especially since the interventions were originally designed to reach both males and females. Some suggest that gender differences may vary or become more obvious as children become adolescents, with hormonal and environmental differences between sexes emerging at that challenging stage of development [34–36]; however, gender differences were observed with children as young as 8 years. The differential results may suggest that mediators for SB or anthropometric changes may be different between males and females; thus, future interventions may need to be tailored specific to gender.

Obesity rates are disproportionate across the ethnicities and socioeconomic status (SES) groups. Reducing such inequalities in childhood obesity is imperative. Some of the studies did address such disparities by either specifically designing interventions to reach certain at-risk populations, such as AA girls or schools in low-SES areas [29, 30], or by evaluating results across race/ethnicity or SES groups. However, such study designs and data analysis were limited, warranting further interventions to focus on specifically addressing such inequalities.

4.4. Costs. Understanding the costs related to recruitment and implementation of an intervention and its potential cost effectiveness are important aspects to consider when a health practitioner must determine how best to utilize the often-limited resources that are available in community or school settings. In this systematic paper, we aimed to collect any evidence related to cost of the interventions. While there is a need to understand cost-related issues of interventions, unfortunately, as reported in other publications [37], data on cost of the interventions identified for this paper were very limited. Measuring costs related to the different stages of the research process should be incorporated into study designs, and such data should be included when reporting intervention effects.

4.5. Limitations. There were several limitations to the paper. Similar to other papers, this systematic paper is limited by the quantity and quality of the studies that were identified. A qualitative analysis of the evidence was warranted due to the variations in study design and characteristics, including intervention and follow-up duration, strategies used, population, and measurement outcomes. Measurements of SB were mainly self-report; however, to minimize this potential bias, some studies did use measures with high validity and reliability. In addition, the majority of the studies were conducted in the US, which may limit the generalizability to other countries, where cultural values and behavioral patterns of SB may differ.

5. Implications

5.1. For Future Research. This systematic paper highlights the need for future research to further explore the reduction of SB in relation to preventing and treating childhood obesity. More comprehensive study designs, which include postintervention follow-up measures, are warranted to better understand the impact and potential sustainability of different strategies on outcomes measures related to SB and anthropometry. Additionally, as SB data were mainly self-report, more valid and reliable measures of SB should be developed. Furthermore, addressing childhood obesity inequalities related to race/ethnicity, SES and gender need to be further explored and should be incorporated into the design of future interventions. In addition, a review on cost of the interventions was not possible due to the paucity of available data, thus collecting data related to cost would provide more comprehensive data for public health practitioners to allow them to determine which interventions may be most effective in their settings.

5.2. For Public Health. Many of these interventions, while comprehensive, were designed to be incorporated into the regular school classroom with teachers delivering the lessons. Others were designed to be implemented in convenient locations within communities, and sessions could be led by those without extensive health training or education. One study [27] specifically mentioned that the intervention was designed to make it easily applicable to real-life settings. These study designs point to the important consideration of the often-challenging aspect of feasibility when implementing interventions in real-world settings and highlight interventions that may have a "true public health impact" [38] as behavioral science research must be "contextual" and "practical" [39].

A very limited number of the studies focused on interventions that modified school policies and the physical environment in ways that support improved dietary practices and regular PA. Often such interventions are not candidates for reviews because of their limited outcome measures on specific behaviors or weight-related outcomes. However, such strategies are gaining support and have the potential to make a significant and sustainable impact [40].

In conclusion, interventions aimed at reducing SB appear to be effective in decreasing SB and improvements in anthropometric measures of childhood obesity. In addition, several of the studies did consider elements of feasibility and applicability in real-world settings to increase potential translation of research interventions into practice settings. Childhood obesity is a complex epidemic with various contributing factors at multiple levels. To make an impact on reversing the trends, a combined effort of strategies that address multiple determinants, including SB, across multiple settings, such as the school, community, clinic, and household is needed.

Conflict of Interests

The authors declare that they have no conflict of interests.

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Review Article

A Review of Different Behavior Modification Strategies Designed to Reduce Sedentary Screen Behaviors in Children

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Previous research suggests that reducing sedentary screen behaviors may be a strategy for preventing and treating obesity in children. This systematic review describes strategies used in interventions designed to either solely target sedentary screen behaviors or multiple health behaviors, including sedentary screen behaviors. Eighteen studies were included in this paper; eight targeting sedentary screen behaviors only, and ten targeting multiple health behaviors. All studies used behavior modification strategies for reducing sedentary screen behaviors in children (aged 1–12 years). Nine studies only used behavior modification strategies, and nine studies supplemented behavior modification strategies with an electronic device to enhance sedentary screen behaviors reductions. Many interventions (50%) significantly reduced sedentary screen behaviors; however the magnitude of the significant reductions varied greatly (-0.44 to -3.1 h/day) and may have been influenced by the primary focus of the intervention, number of behavior modification strategies used, and other tools used to limit sedentary screen behaviors.

1. Introduction

It is well established that excessive sedentary time, independent of too little exercise, leads to a number of negative health outcomes [1–8]. Collectively, leisure-time screen behaviors, such as television (TV), videos, DVDs, video games, and computers, have been associated with increased inactivity [9] and metabolic risk factors [10]. Children are accumulating a considerable amount of sedentary screen time, particularly TV viewing [11–13], and some are not getting adequate amounts of physical activity in their leisure time [14]. For children and adolescents, overweight and obesity have been linked to sedentary leisure-time activities [15–18].

Obesity levels in children and adolescents (aged 6 through 19 years) have tripled over the past 35 years [19]. Thirty-one percent of American children are overweight or obese (as defined as being at or above the 85th percentile for body mass index (BMI) based on the Centers for Disease Control and Prevention Growth Charts) [20]. Strategies for decreasing the current rate of childhood obesity are needed due to the physiological and psychological health risks associated with childhood obesity [21]. Because childhood obesity tracks into adulthood [22], these health risks have the potential to be present for a lifetime.

This rise in childhood obesity has been associated with reduced levels of physical activity (energy expenditure), increased consumption of food (energy intake), or both [13, 14, 23, 24]. Sedentary screen behaviors, especially TV watching, are hypothesized to contribute to weight gain by reducing opportunities for energy expenditure and increasing energy intake [25–27]. Time spent engaging in TV watching can compete with time spent in other activities that require greater amounts of energy [18, 28, 29]. Also, TV watching is often coupled with unhealthy eating behaviors (e.g., increased consumption of soft drinks, fried foods, and snacks) due to influential environmental cues such as food and beverage commercials and easy access to food [25, 30–32]. Thus, sedentary screen behaviors may influence both sides of the energy balance equation.

Partially due to the negative health effects of sedentary screen media, the American Academy of Pediatrics recommends limiting children's total entertainment media time to less than 2 h/day [33]. According to recent Kaiser Family Foundation data, the average child or adolescent (8–18 years) spends an average of nearly 7 h/day using screen-based media (i.e., TV, movies, videogames, computer), [12] with more than half of that time spent watching TV [12, 13]. TV watching is the most prominent leisure-time activity [34–36]. In 2009, among children aged 8–18 years, TV viewing time averaged 4.5 h/day [12]. Based on the results from the 2001–2006 National Health and Nutrition Examination Survey, 47% of children aged 2 to 15 years spent 2 or more h/day using screen-based media, and 33% of children engaged in TV/video viewing alone for 2 or more h/day [13]. Secondary school-aged boys averaged more TV on weekend days than weekdays [34]. Children in primary school spend 2 to 4.5 h/day watching TV, and preschool children spend 2 to 2.5 h/day watching TV [37–39]. Childhood TV viewing habits have been associated with overweight, poor fitness, smoking, and high cholesterol levels in adulthood [40], and several studies have found that sedentary screen behaviors track more strongly from childhood to adulthood than physical activity [41–43].

The prevalence of media in children's lives and its association with obesity have prompted research on methods to reduce media consumption in children. Attempts to change leisure-time behaviors in children/adolescents have taken two primary avenues: (1) increasing physical activity, and (2) reducing sedentary screen behaviors (TV/video watching, video/computer games, and computer use, etc.). Both behaviors can affect energy balance, but reducing sedentary screen behaviors may be easier to accomplish [44]. Sedentary behaviors, like other behaviors, are shaped by the interaction of many individual factors within the broader social and environmental contexts [45]. Therefore, behavior change interventions that are theoretically based may prove more effective than atheoretical approaches [46, 47].

The results from several studies in children suggest that reducing sedentary screen time alone, or as part of a more comprehensive program, may be a promising strategy for preventing and treating obesity [48–50]. Information on different methods of reducing sedentary behaviors can help in the design of more effective interventions in this growing field of research.

Thus, the purpose of this paper is to review randomized controlled trials that have incorporated strategies for reducing sedentary behaviors in children aged 0 to18 years. This paper examines the specific behavior modification strategies used and documents the frequency of their use in randomized controlled trials targeting a reduction in sedentary screen behaviors. We separate studies into those that focused specifically on reducing sedentary behaviors and those that focused on changing multiple health behaviors, including reducing sedentary screen behaviors. The theoretical background of the strategies used for behavior change is also listed. The different measures (self-report or electronic) used to assess sedentary behavior are highlighted. Finally, recommendations are provided regarding the types of interventions that appear to be most effective in reducing sedentary screen behaviors.

2. Methods

2.1. Study Criteria. This systematic review identified studies that attempted to reduce sedentary behaviors in children (1 to 12 years of age). The initial search's age range was 0 to 18 years, but no studies were identified with children outside the 1- to 12-year-old age range. Only trials intended to reduce sedentary screen behaviors were included in this paper. Studies that did not describe group assignment strategies were considered to be nonrandom in assignment and thus excluded from this paper.

For inclusion in the paper, randomized controlled trials were required to have a clear focus on reducing sedentary screen behaviors, particularly TV watching, and this reduction in sedentary screen behaviors had to be one of the reported outcomes of interest. While some studies specifically targeted TV viewing, other studies targeted TV viewing as part of reducing multiple sedentary screen behaviors. In some studies, the reduction in sedentary screen behavior was the primary objective, while in others it was measured as a secondary aim, with changes in body weight or BMI as the primary aim. Multiple behavior interventions that included reductions in sedentary behavior in addition to other modalities (diet and exercise) were also eligible for inclusion in this paper. This paper separated findings based on whether the intervention focused only on reducing sedentary screen behaviors or whether it focused on multiple health behaviors, including sedentary screen behaviors. Because the strategies and targets may be different for younger versus older children, study findings were presented by age in the Tables.

2.2. Search Strategy. A search was conducted using the PubMed database. We used a combination of Medical Subject Headings (MeSH) and keywords. MeSH selections included such terms as *Television, Motor Activity, Health Promotion/methods, Overweight/prevention and control, Overweight/rehabilitation, Overweight/therapy, Behavior Therapy, Overweight, Time Factors, Television/utilization*. Keywords included *sedentary*, *screen time, television viewing*, *and television watching* in combination with such keywords as *reduce, reduction, and limit*. Results were limited to randomized controlled trials from 1985 to 2010, for children/adolescents aged 0–18 years, and articles written in English only. One independent reviewer (J. A. Steeves) screened the titles and abstracts of all studies identified by the PubMed search to determine potentially relevant studies. In the initial step of screening, he excluded studies that did not have a reduction of sedentary screen behaviors intervention component or that did not report changes in sedentary screen behaviors

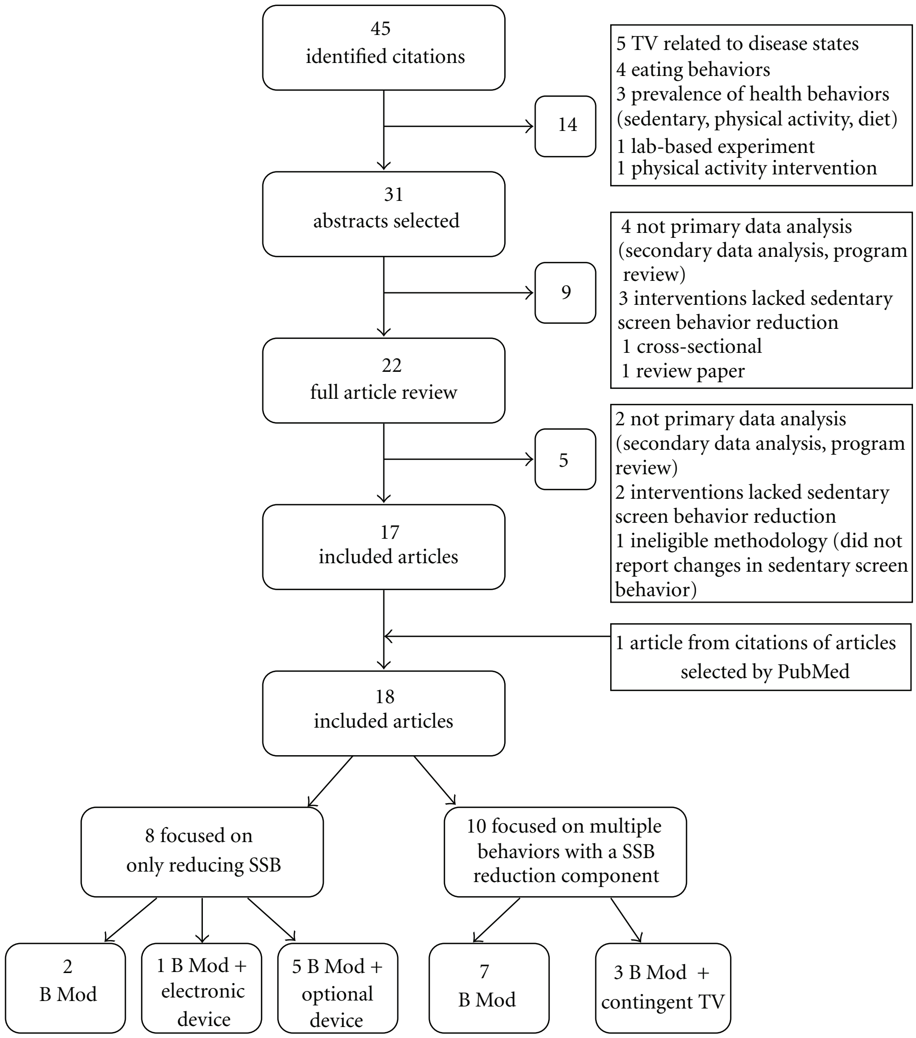

Figure 1: SSB: sedentary screen behavior; B Mod: behavior modification techniques.

as an outcome variable. Examples of the types of studies excluded during this initial step included the following: studies that were secondary data analysis; cross-sectional studies examining the relationship between TV viewing and eating behaviors, activity behaviors, other behaviors, or disease states; studies evaluating commercial weight-loss programs that did not involve a sedentary screen behavior reduction component; laboratory-based studies; prevalence of sedentary screen behaviors use studies. Following the initial screening process, selected articles were reviewed by J. A. Steeves. Full text articles that met all inclusion criteria were included in the paper.

3. Results

3.1. Identified Studies. The preliminary search of PubMed identified 45 citations, and of those, 31 abstracts were selected and reviewed. Twenty-two abstracts met the inclusion criteria and full manuscripts were examined in further detail. Upon full article review, five articles were removed for the following reasons: not primary data collection (secondary data analysis, program review) ($n = 2$); intervention did not involve a sedentary behavior reduction ($n = 2$); not reporting baseline or changes in sedentary behaviors ($n = 1$). See Figure 1 for complete rationale of exclusion. Of the initial 45 citations, 17 articles met all study criteria. One additional article, not discovered in the initial search, was added to the final selection from the citations of selected articles. A total of 18 were included for review. All studies were published between 1999 and 2010 in refereed journals. Depending on the study, sedentary screen behaviors could include: recreational screen time, TV, DVD, VHS, video games, computer games, or internet. Sedentary screen behaviors did not include educational activities such as reading or doing homework on the computer.

The 18 studies included in this systematic review measured comparable outcomes with varying methodologies. Tables 1 and 2 summarize the characteristics of studies that only focused on sedentary screen behaviors and studies

Table 1: Characteristics of randomized controlled trials focused on only reducing sedentary screen behaviors organized by method of reduction and age of children ($N = 8$).

Source	N, age (y), % girls	Delivery location, delivery target, duration	Treatment groups	Target behaviors and SSB goal(s)	Theoretical perspective, strategy to change SSB	Measure of SSB outcomes
Interventions using behavior modification techniques only						
Dennison et al. 2004 [51]	(i) 77 (ii) 2.5–5.5 (iii) 50%	(i) Preschool/day care (ii) Child focused (iii) 7 sessions, 12 mos	(1) Modified curriculum (↓ TV) (2) Modified curriculum (health and safety)	(i) ↓ TV and video (ii) Mealtime TV turn off, wk without TV (1)	(i) Not reported (ii) 4 B Mods: (preplan, + reinforcement, prob solve, stim control) (1)	Self-report: parent report (recall)
Escobar-Chaves et al. 2010 [52]	(i) 202 (ii) 6–9 (iii) 48.5%	(i) Multispecialty medical practice (ii) Child and parent focused (iii) 2-h workshop and 6 newsletters, 6 mos	(1) Parent and child activities (2) No treatment control	(i) TV and other media (DVD, video, handheld games, and computer) (ii) ↓ TV (turn TV off if not watching, no TV at meals, no TV in bedrooms)	(i) Social cognitive theory (ii) 4 B Mods: (preplan, prob solve, social support, stim control); skill dev training and coaching (1)	Self-report: parent report (recall)
Interventions using behavior modification techniques plus a mandatory electronic TV monitoring device						
Epstein et al. 2008 [53]	(i) 70 (ii) 4–7 (iii) 47%	(i) University children's hospital (ii) Child and parent focused (iii) 6 meetings (1/mos), 18 newsletters (1/mos), 24 mos	(1) TV device and monthly newsletter (2) Normal access to TV and computers	(i) TV and computer (ii) ↓ TV by 50%	(i) Not reported (ii) 3 B Mods: (goal set, + reinforcement, stim control); TV device (1)	Electronic: TV Allowance
Interventions using behavior modification techniques plus an optional electronic TV monitoring device						
Ford et al. 2002 [54]	(i) 28 (ii) 7–12 (iii) 53.6%	(i) Urban community primary care clinic (ii) Child and parent focused (iii) Single session, 1 mos	(1) Counseling and education, plusTV device (2) Counseling and education	(i) TV, videotape, and video games (ii) TV budget	(i) Social cognitive theory (ii) 3 B Mods: (goal set, stim control, self-monitor); optional TV device (1)	Self-report: parent aided child report (recall)
Robinson 1999 [49]	(i) 92 (ii) 8–10 (iii) 46.7%	(i) Elementary school (ii) Child and parent focused (iii) 18 sessions, 7 mos	(1) Modified curriculum (2) Usual school curriculum	(i) TV, videotape, and video games (ii) 10 day TV turnoff, ↓ SSB 7 h/wk	(i) Social cognitive theory (ii) 5 B Mods: (goal set, preplan, stim control, self-monitor, social support); optional TV device (1)	Self-report: parent and child report (recall)

Table 1: Continued.

Source	N, age (y), % girls	Delivery location, delivery target, duration	Treatment groups	Target behaviors and SSB goal(s)	Theoretical perspective, strategy to change SSB	Measure of SSB outcomes
Robinson et al. 2003 [55]	(i) 61 (ii) 8–10 (iii) 100%	(i) Community centers and home visits (ii) Child and parent focused (iii) 60 dance classes, 5 in home lessons, 5 newsletters, 3 mos	(1) After school dance, home- based behavioral treatment, and TV device (2) Information-based health education	(i) TV, videotape, and video games (ii) ↓ TV (2-wk TV-turnoff)	(i) Social cognitive theory (ii) 5 B Mods: (goal set, modeling, stim control, self-monitor, social support); optional TV device (1)	Self-report: child report (recall)
Todd et al. 2008 [56]	(i) 21 (ii) 8–11 (iii) 0%	(i) University research unit (ii) Child and parent focused (iii) 5 monthly meetings, 3 newsletters, and weekly phone contact	(1) Seminar on ↓ media use (2) Control group	(i) Electronic media (TV, movies, videos, video games, and nonschool related computer and internet use) (ii) ↓ ST $\leq$ 90 min/day	(i) Not reported (ii) 4 B Mods: (goal set, preplan, self-monitor, social support); optional TV device and computer software to limit computer and internet use (1)	Self-report: child report (log books)
Ni Mhurchu et al. 2009 [57]	(i) 29 (ii) 9–11 (iii) 38%	(i) University research unit (ii) Child and parent focused (iii) Single session, 2 mos	(1) Counseling, education, plus TV device (2) Counseling and education	(i) TV and total ST (video games, computer, and DVDs) (ii) ↓ TV 1 h/day	(i) Not reported (ii) 5 B Mods: (goal set, preplan, prob solve, stim control, self-monitor); optional TV device (1)	Self-report: child report (recall)

N: number of participants randomized to conditions; y: years; SSB: sedentary screen behaviors; B: behavior; mos: months; wk: week; numbers in the ( ) in column 5 and 6: treatment groups; B Mods: behavior modification techniques; plan: planning; +: positive; prob solve: problem solving; stim: stimulus; h: hour; dev: development; set: setting; monitor: monitoring; ST: screen time; min: minutes.

TABLE 2: Characteristics of randomized controlled trials focused on multiple behaviors with a sedentary screen behaviors reduction component organized by method of reduction and age of children ($N = 10$).

Source	N, age (y), % girls	Delivery location, delivery target, duration	Treatment groups	Target behaviors and SSB goal(s)	Theoretical perspective, strategy to change SSB	Measure of SSB outcomes
Interventions using behavior modification techniques only						
Whaley et al. 2010 [58]	(i) 589 (ii) 1–5 (iii) NR	(i) WIC program (ii) Parent focused (iii) 2 sessions, 12 mos	(1) Enhanced WIC individual nutritional education (2) Routine WIC individual nutrition education	(i) Food and beverage intake, PA and TV (ii) NR	(i) Stages of change theory, transtheoretical model (ii) 3 B Mods NR for specific B: (goal set, preplan, prob solve); motivational interviewing (1)	Self-report: parent report (recall)
Epstein et al. 2000 [59]	(i) 90 (ii) 8–12 (iii) 68.4%	(i) Childhood obesity research clinic (ii) Child and parent focused (iii) 20 sessions, 6 mos	(1) ↓ SB high (20 h/wk) (2) ↓ SB low (10 h/wk) (3) ↑PA high (20 mi/wk) (4) ↑ PA low (10 mi/wk)	(i) SB (TV, video, computer games, board games, or talking on the phone) and diet (ii) ↓ SB 20 h/wk (1), ↓ SB 10 h/wk (2)	(i) NR (ii) 6 B Mods for both SB and diet: (B contract goal set, preplan, + reinforcement, prob solve, self-monitor) (1, 2, 3, 4)	Self-report: parent aided child report (recall)
Epstein et al. 2004 [60]	(i) 63 (ii) 8–12 (iii) 61.9%	(i) Childhood obesity research clinic (ii) Child and parent focused (iii) 20 sessions, 6 mos	(1) Reinforced ↓ SSB (15 h/wk) (2) Stim control ↓ SSB (15 h/wk)	(i) TV, VCR/DVDs, video games, or computer use not for school, and diet (ii) ↓ SSB (15 h/wk) (1, 2)	(i) NR (ii) 4 B Mods for reinforced ↓ SSB: (B contract, goal set, + reinforcement for ↓ SSB, self-monitor); (iii) 3 B Mods for stim control of SSB: (goal set, self-monitor, stim control); (iv) 4 B Mods for diet: (goal set, preplan, + reinforcement, self-monitor)	Self-report: parent aided child report (log books)
Harrison et al. 2006 [61]	(i) 312 (ii) 9–11 (iii) 43%	(i) Elementary school (ii) Child focused (iii) 10 lessons, 4 mos	(1) Modified curriculum (2) Usual health curriculum	(i) ST (TV, videotape/DVD, or computer games) and PA (ii) ↓ ST	(i) Social cognitive theory (ii) 7 B Mods used for both ST and PA: (goal set, preplan, + reinforcement, prob solve, relapse prev, self-monitor, social support)	Self-report: child report (recall)
Gentile et al. 2009 [62]	(i) 1323 (ii) 9–11 (iii) 53%	(i) Mailings to home, community, elementary school (optional) (ii) Child and parent focused (iii) 9 mos community ad campaign, and 9 mailings, 9 mos	(1) Enhanced school curriculum (optional), behavioral tools packets mailed home, community ad campaign (2) Regular school curriculum, no materials mailed home, community ad campaign	(i) PA, ST (TV and video games), and F and V ↓ (ii) ST 2 h/day	(i) Not reported (ii) 5 B Mods used for PA, ST and F and V: (goal set, preplan, + reinforcement, prob solve, self-monitor) (1)	Self-report: parent and child report (recall)

Table 2: Continued.

Source	N, age (y), % girls	Delivery location, delivery target, duration	Treatment groups	Target behaviors and SSB goal(s)	Theoretical perspective, strategy to change SSB	Measure of SSB outcomes
Salmon et al. 2008 [63]	(i) 311 (ii) 10–11 (iii) 51.3%	(i) Elementary school (ii) Child and parent focused (iii) 19 sessions, 9 mos	(1) ↓ TV through B-Mod-based curriculum (2) ↑skills through modified PE curriculum (3) ↓ TV and ↑ skills curriculums (4) Usual class and PE curriculum	(i) Rec screen B (TV, computer, and electronic games), and PA (ii) ↓ ST (switch-off one program per wk over 4 wk period)	(i) Social cognitive theory and behavioral choice theory (ii) 7 B Mods used for ST: (B contract, goal set, preplan, prob solve, self-monitor, stim control, + reinforcement) (1, 3) (iii) 3 B Mods used for PA: (self-monitor, preplan, prob solve)	Self-report: child report (recall)
Gortmaker et al. 1999 [48]	(i) 1295 (ii) 10–12 (iii) 48%	(i) Middle school (ii) Child focused (iii) 32 lessons, 24 mos	(1) Modified curriculum (2) Regular school curriculum	(i) F and V intake, PA, total calories, and % calories from fat, TV (ii) ↓ TV 2 h/day(1)	(i) Social cognitive theory, and behavioral choice theory (ii) B Mods NR	Self-report: child report (recall)
Interventions using behavioral modification techniques plus contingent TV						
Faith et al. 2001 [50]	(i) 10 (ii) 8–12 (iii) 30%	(i) Obesity research center (ii) Child focused (iii) 3 mos	(1) TV contingent upon cycling ergometer (2) TV not contingent upon cycling ergometer	(i) PA and TV (ii) 1 min cycling = 2 min TV (1)	(i) Behavioral choice theory (ii) 1 B Mod used for TV viewing and TV-related PA: (+ reinforcement); and TV cycle (1)	Electronic: microcomputer of the TV cycle
Roemmich et al. 2004 [64]	(i) 18 (ii) 8–12 (iii) 38.9%	(i) Behavioral medicine laboratory (ii) Child and parent focused (iii) 6 wkly meetings, 6 wks	(1) Open-loop feedback of PA plus + reinforcement (2) No feedback, no + reinforcement	(i) PA and TV, video, DVD, and video games (ii) 400 activity counts = 60 min of TV (1)	(i) Reinforcement theory (ii) 4 B Mods used for PA and TV: (+ reinforcement); and TV device (1); (goal set, prob solve, self-monitor) (1, 2)	Self-report: child report (log book)
Goldfield et al. 2006 [65]	(i) 30 (ii) 8–12 (iii) 56.5%	(i) Children's hospital research institute (ii) Child and parent focused (iii) Bi-wkly meetings, 2 mos	(1) Open-loop feedback of PA plus + reinforcement (2) Open-loop feedback of PA	(i) PA and TV, VCR/DVD, and video games (ii) 400 counts on pedometer = 160 min of TV (1)	(i) Reinforcement theory (ii) 3 B Mods used for PA and TV: (goal set, + reinforcement, self-monitor); TV device (1)	Self-report: child report (recall)

N: number of participants randomized to conditions; y: years; SSB: sedentary screen behaviors; B: behavior; NR: not reported; mos: months; PA: physical activity; B Mods: behavior modification techniques; set: setting; plan: planning; prob solve: problem solving; numbers in the ( ) in column 5 and 6: treatment groups, SB: sedentary behaviors; h: hours; wk: week; mi: miles; B contract: behavioral contracting; +: positive; monitor: monitoring; stim: stimulus; ST: screen time; prev: prevention; ad: advertisement; F and V: fruits and vegetables; PE: physical education, Rec screen B: recreational screen behaviors; min: minutes.

Table 3: Outcomes of randomized controlled trials focused on only reducing sedentary screen behaviors organized by method of reduction and age of children ($N = 8$).

Source	Treatment group	Change in SSB (h/day) Intervention, mos	Change in SSB (h/day) Followup, mos	% change in SSB Intervention, mos	% change in SSB Followup, mos
Interventions using behavior modification techniques only					
Dennison et al. 2004 [51]		0–12	None	0–12	None
	1	−0.44*		−26%*	
	2	+0.23		+11%	
Escobar-Chaves et al. 2010 [52]		0–6	None	0–6	None
	1	−0.53		−25%	
	2	−0.53		−21%	
Interventions using behavior modification techniques plus a mandatory electronic TV monitoring device					
Epstein et al. 2008 [53]		0–24	None	0–24	None
	1	−2.5*		−72%*	
	2	−0.74		−20%	
Interventions using behavior modification techniques plus an optional electronic TV monitoring device					
Ford et al. 2002 [54]		0-1	None	0-1	None
	1	−2.0		−26%	
	2	−2.0[b]		−36%[b]	
Robinson 1999 [49]		0–6	None	0–6	None
	1:child reported	−0.94*		−43%*	
	1:parent reported	−0.51*		−6.5%*	
	2:chid reported	−0.14		−28%	
	2:parent reported	−0.02		−1.0%	
Robinson et al. 2003 [55]		0–3	None	0–3	None
	1	−0.41		−15%	
	2	+0.10		+3.2%	
Todd et al. 2008 [56]		0–2.5	0–5	0–2.5	0–5
	1	−1.2[b]	−1.18	−47%[b]	−46%
	2	−0.63	−1.03	−24%	−40%
Ni Mhurchu et al. 2009 [57]		0–2	None	0–2	None
	1	−0.60		−31%	
	2	−0.01		−0.8%	

SSB: sedentary screen behaviors; h: hour; treatment group: group assignment (1: treatment group, 2: control group); mos: months; *: significant difference between groups; [b]: significantly different from baseline value.

that focused on changing multiple behaviors, respectively. Tables 3 and 4 summarize the changes in sedentary screen behaviors in those interventions that only targeted sedentary screen behaviors and those interventions that focused on changing multiple behaviors, respectively. Each of the tables separates the studies by the types of strategies used to change sedentary screen behaviors and then organizes studies in ascending order based upon the age of the participants, with studies with the youngest participants listed first. Tables 1 and 2 include a summary of each study documenting sample size, age, gender, location of delivery, primary target(s) of intervention delivery, duration, treatment groups, targeted behaviors and goals associated with reducing sedentary screen behaviors, theoretical perspective and strategies to reduce sedentary screen behaviors, and the method of measurement of the sedentary screen behaviors. Tables 3 and 4 summarize the study outcomes on sedentary screen behaviors. The results below provide an overview of the general characteristics and outcomes of all 18 studies.

Forty-four percent of the studies focused solely on reducing sedentary screen behaviors, with 63% of these studies having sedentary screen behavior changes as their primary dependent variable. Change in BMI was the primary dependent variable in the other 37%. Fifty-six percent of the studies focused on changing multiple health behaviors, and either had weight change as the primary dependent variable (40%) or had multiple primary dependent variables (obesity, BMI, physical activity, sedentary screen behaviors, diet, etc.) (60%). Four types of sedentary screen behavior reduction interventions were identified in this paper: (1) sedentary screen behavior reduction interventions using behavior modification components ($n = 9$); (2) sedentary

Table 4: Outcomes of randomized controlled trials focused on multiple behaviors with a sedentary screen behaviors reduction component organized by method of reduction and age of children ($N = 10$).

Source	Treatment group	Change in SSB (h/day)		% change in SSB	
		Intervention, mos	Followup, mos	Intervention, mos	Followup, mos
Interventions using behavior modification techniques only					
Whaley et al. 2010 [58]		0–6	0–12	0–6	0–12
	1	Not reported	+0.30*	Not reported	+13%*
	2		+0.60		+26%
Epstein et al. 2000 [59]		0–6	0–24	0–6	0-24
	(1) ↓ SSB high (20 h/wk)	Not reported	Not reported	−20%[b]	−12%[b]
	(2) ↓ SSB low (10 h/wk)			−15%[b]	−0.6%[b]
	(3) ↑ PA high (20 mi/wk)			−9.4%[b]	−8.4%[b]
	(4) ↑ PA low (10 mi/wk)			−6.5%[b]	−11%[b]
Epstein et al. 2004 [60]		0–6	0–12	0–6	0–12
	1-stimulus control	Not reported	Not reported	−2.2%[b]	Not reported
	2-reinforced reduction			−2.2%[b]	
Harrison et al. 2006 [61]		0–4	None	0–4	None
	1	−0.61		−21%	
	2	−0.40		−13%	
Gentile et al. 2009 [62]		0–9[a]	0–15[a]	0–9[a]	0–15[a]
	1-child reported	+0.55	−0.11	+13%	−2.9%
	1-parentreported	+0.30*	+0.43*	+10%*	+14%*
	2-child reported	+0.09	−0.21	+2.0%	−4.9%
	2-parent reported	+0.19	+0.34	+5.6%	+10%
Salmon et al. 2008 [63] (b-coefficients)		0–9	0–12	0–9	0–12
	1	+0.55*	+0.57*	Not reported	Not reported
	2	+0.36	+0.34		
	3	+0.33	+0.34		
Gortmaker et al. 1999 [48]		0–24	None	0–24	None
	1-male	−0.70*		−19%*	
	1-female	−0.70*		−23%*	
	2-male	−0.35		−9.3%	
	2-female	−0.11		−3.6%	
Interventions using behavioral modification techniques plus contingent TV					
Faith et al. 2001 [50]		0–3	None	0–3	None
	1	−3.1*		−95%*	
	2	−0.26		−9.1%	
Roemmich et al. 2004 [64]		0–1.5	None	0–1.5	None
	1	−0.33		Not reported	
	2	+0.22			
Goldfield et al. 2006 [65]		0–2	None	0–2	None
	1	−1.9*		−72%*	
	2	+0.24		+9.5%	

SSB: sedentary screen behaviors; h: hour; treatment group: group assignment (1: treatment group, 2: control group); mos: months; wk: week; mi: miles, Salmon et al. 2008 [63]; 1: ↓ TV through behavioral modification based curriculum, 2: ↑ skills through modified physical education curriculum, 3: ↓ TV and ↑ skills curriculums); *: significant difference between groups; [a]: Significant difference in reported TV viewing time between parents and children; [b]: significantly different from baseline value.

screen behavior reduction interventions with behavioral modification plus optional use of an electronic TV monitoring device ($n = 5$); (3) sedentary screen behavior reduction interventions that used behavioral modification and mandatory use of an electronic device that limited screen time ($n = 1$); (4) sedentary screen behavior reduction interventions with behavior modification plus contingent TV (i.e., access to TV was based upon completing certain tasks or exercising for a certain amount of time) ($n = 3$).

While the majority (61%) of these behavior change intervention strategies were theoretically based, 39% of reviewed studies did not report the theory upon which they were based [51, 53, 56, 57, 59, 60, 62]. Of all the studies, 27% of intervention strategies were based on social cognitive theory [49, 52, 54, 55, 61], 11% were grounded on both social cognitive and behavioral choice theory [48, 63], 11% were based on reinforcement theory [64, 65], one (6%) was based on behavioral choice theory [50], and one (6%) was based on the transtheoretical model [58].

The ages of the children included in these studies ranged from 1 to 12 years. Eighty-three percent of the studies targeted children between the ages of 6 and 12 years [48–50, 52, 54–57, 59–65], with 72% targeting children between the ages of 8 and 12 years [48–50, 55–57, 59–65]. Two studies (11%) included children aged 1 to 5 years exclusively [51, 58], and one study (6%) included children aged 4 to 7 years [53]. Eighty-eight percent of the studies included both male and female participants. One study (6%) included only males [56], and one study (6%) included only females [55]. Sample sizes ranged from 10 to 1323 participants. Study durations ranged from 1 to 24 months.

The majority (55%) of the interventions were delivered through research centers (i.e., universities, physicians clinic, medical centers) [50, 52–54, 56, 57, 59, 60, 64, 65], or through schools or preschools (27%) [48, 49, 51, 61, 63]. One study (6%) was delivered through the federally funded health and nutrition program for women, infants, and children (WIC) [58], one study (6%) delivered a multilevel program (family, community, and school) [62], and one intervention (6%) was delivered through community centers and home visits [55]. Most interventions (72%) focused their delivery towards both the child and the parent [49, 52–57, 59, 60, 62–65], some interventions (22%) focused primarily on delivering the messages to the child [48, 50, 51, 61], and one intervention (6%) focused delivery solely on the caregiver/parent [58].

Self-report (child only, parent only, and parent-assisted, or parent and child) of sedentary screen behaviors was the method used most frequently (89%) to assess changes in behaviors. Forty-four percent of studies relied on child (ages 8–12 years) self-report (six used recall questionnaires, two used activity log books) [48, 55–57, 61, 63–65], 17% relied on parental report (recall questionnaires) of their children's (ages 1–9 years) sedentary screen behaviors [51, 52, 58], 17% used parent-assisted report (two used recall questionnaires, one used activity log books) of the child's (ages 7–12 years) sedentary screen behaviors [54, 59, 60], and 11% used separate parent and child reports (recall questionnaires) of the child's (ages 8–11 years) sedentary screen behaviors [49, 62]. Two studies (11%) used an electronic device (one used the TV Allowance, one used the TV cycle microcomputer) to record screen time usage in children (ages 4–12 years) [50, 53].

3.2. Randomized Controlled Trials Focused on Only Reducing Sedentary Screen Behaviors

3.2.1. Interventions That Used Behavior Modification Techniques Only. Two studies used behavior modification techniques alone in interventions to reduce sedentary behaviors [51, 52]. A total of five different behavior modification techniques, preplanning, positive reinforcement, problem solving, stimulus control, and social support, were provided to the children in these two studies to help with reducing sedentary screen behaviors. Three behavior modification techniques were used in both of these studies: preplanning, problem solving, and stimulus control. Five behavioral modification strategies were used in one study [51], and Escobar-Chaves et al. [52] used four behavior modification techniques plus skill development training and coaching.

Both studies appeared to reduce sedentary screen time. One intervention successfully reduced TV viewing in the intervention group (−0.44 h/day, or 26%) [51] when compared to the control group. The other study showed a trend towards reducing total media consumption in the intervention group (−0.53 h/day or 25%) [52]. Results from these interventions suggest that when only sedentary screen time behaviors are targeted, behavioral modification strategies successfully reduce these behaviors.

3.2.2. Interventions That Used Behavioral Modification and Mandatory Use of an Electronic Device. One intervention used an electronic device (TV Allowance) to supplement behavior modification techniques to reduce TV viewing and computer time [53]. The TV Allowance turned off the TV and computer screens and did not allow them to be turned on again once the weekly preprogrammed amount of time was met [53]. Thus, it enforced a weekly time budget (a reduction of 10% of their baseline amount per month; up to a 50% reduction) for use of the TV and computer games. Along with the TV Allowance, three behavior modification techniques were used: goal setting, positive reinforcement, and stimulus control.

The TV Allowance and behavior modification strategies reduced sedentary screen time by 2.5 h/day, or 72% from baseline [53]. Combining technology with behavior modification techniques substantially reduced sedentary screen time.

3.2.3. Interventions That Used Behavioral Modification Plus Optional Use of an Electronic TV Monitoring Device. Five studies combined the use of an optional electronic TV monitoring device (i.e., TV Allowances or Token TV) with behavioral modification strategies [49, 54–57]. While the electronic TV monitoring devices were attached to participants' TVs, they were not a mandatory part of the intervention treatment. Besides setting limits, these devices can help participants to self-monitor TV watching [66]. In addition to the optional use of the electronic TV monitoring device provided to the families in each of these studies, a total of seven different behavior modification techniques were used to help the children reduce their sedentary screen behaviors, including: goal setting, modeling, preplanning, problem solving, stimulus control, self-monitoring, and social support. The three most frequently used behavior modification techniques used in these interventions were goal setting, self-monitoring, and stimulus control. An average of four behavior modification strategies were incorporated into these studies, with three studies using five [49, 55, 57], one study using four [56], and one study using three behavior modification techniques [54].

Two of the five studies reported significant reductions in sedentary screen time [49, 56]. One of the five TV reduction interventions that augmented their behavioral modification techniques with the electronic TV monitoring device reported significant reductions in TV viewing from baseline [56]. In this study, participants in the experimental group experienced a significant reduction in electronic media of 1.2 h/day or 47% after 10 weeks and maintained this reduction at 20 weeks (reduction of 1.18 h/day or 46%) [56]. One study reported a significant reduction in TV viewing compared to the control children [49]. In these studies, the magnitude of the significant TV viewing reductions varied from 0.5 h/day or 0.94 h/day [49] to 1.2 h/day [56], or from 7% or 43% [49] to 47% [56] from baseline levels.

Three studies showed no significant decreases in sedentary behaviors [54, 55, 57]. One of these studies showed a trend towards a reduction in media use in an intervention that received a 5–10 minute counseling session about the problems with excessive media use, along with the TV device and behavior modification training in goal setting, self-monitoring, and stimulus control [54]. In another study [55], although not significant, the treatment group children reduced TV media use by 0.41 h/day in comparison to an increase of 0.10 h/day in the control group. In the third study that did not reach significance [57], the treatment group decreased TV viewing by 0.60 h/day and the control group's daily TV viewing did not change (−0.01 h/day). The three studies that did not significantly reduce media use used a similar number of behavior modification strategies, but they were shorter in duration than the two that did reduce media use.

These studies indicate that behavior modification strategies combined with an optional electronic TV monitoring device may create reductions in sedentary screen time. However, the investigations did not report on the frequency of use for the electronic TV monitoring devices; thus it is not clear how much the devices influenced the outcomes in these investigations.

3.3. Randomized Controlled Trials Focused on Multiple Behaviors with a Sedentary Screen Behaviors Component

3.3.1. Interventions Using Behavior Modification Techniques Only. Seven interventions focused on changing multiple behaviors related to energy balance (i.e., increasing physical activity, decreasing sedentary screen time, reducing sugar sweetened beverages, and increasing fruit and vegetable intake) [48, 58–63] through the use of behavior modification alone. Of these seven multiple behavior interventions, two did not report whether different behavior strategies were applied to each behavior [48, 58], three used all the behavior modification strategies equally to affect all behaviors of interest [59, 61, 62], and two studies applied different behaviors modification techniques' to specific behaviors [60, 63].

Of the two studies that used different techniques for different behaviors, Salmon et al. [63] used behavioral contracts, goal setting, preplanning, problem solving, self-monitoring, stimulus control, and positive reinforcement for reducing sedentary screen behaviors. The behavior modification strategies used for increasing physical activity included: self-monitoring, preplanning, and problem solving. Epstein et al. [60] compared two different methods to reduce sedentary screen behaviors. One group was reinforced for reducing their sedentary screen behaviors and used behavioral contracts, goal setting, self-monitoring, and positive reinforcement for reducing sedentary behaviors. The other group received training in goal setting and self-monitoring and used stimulus control to reduce sedentary screen behaviors. Both groups used the following behavior modification techniques to help change their diet: goal setting, preplanning, positive reinforcement, and self-monitoring [60].

A total of nine different behavior modification techniques were provided to the children in these studies to help with reducing sedentary screen behaviors and included: behavioral contracts, goal setting, pre-planning, positive reinforcement, problem solving, relapse prevention, stimulus control, self-monitoring, and social support. The most frequently used behavior modification techniques were goal setting, positive reinforcement, preplanning, problem solving, and self-monitoring. The average number of behavior modification techniques used in these studies was five. Two studies used a total of seven behavioral modification strategies [61, 63], and there were three other studies that used four or more strategies [59, 60, 62]. One study did not report the behavior modification techniques they used [48], and another study did not specify what behavior modification techniques were used towards what health behaviors [58].

Three of the seven studies showed significant reductions in sedentary screen time [48, 59, 60]. One of the seven interventions was successful in reducing sedentary screen behaviors in the intervention group (−0.7 h/day or −19% in males, and −0.7 h/day or −23% in females) compared to the control group (−0.35 h/day or −9.3% in males, and −0.11 h/day or −3.6% in females) [48]. Two of the seven interventions reported significant reductions (−2.2% to −20%, resp.) in targeted sedentary behaviors from baseline in their intervention groups [59, 60]. Epstein et al. [59] observed a significant decrease in targeted sedentary behaviors in both the low- and high-dose treatment groups for the decrease sedentary activity at 6 months (−15% and

−20%, resp.). The low (10 h/wk) and high (20 h/wk) doses for decreases in sedentary behavior differed in the degree of behavior change required. At the 24-month followup, the high dose decrease in sedentary-behavior group sustained the reduction better than the low-dose decrease in sedentary behavior group (−12% and −0.6%, resp.). In another study [60], obese children significantly and equally decreased sedentary behaviors (−2.2%) when receiving treatment that involved either stimulus control or reinforcement to reduce sedentary screen behaviors. Among these three studies, the magnitude of the significant TV viewing reductions varied from −2.2% [60] to −23% [48] from baseline levels.

Four studies showed no decreases in sedentary behaviors [58, 61–63]. One study targeting parents showed that children in the intervention group watched half as much TV post intervention as children whose parents were in the control group [58]. One study showed no significant change in screen time in intervention schools [61]. According to another study, there were no changes in sedentary behaviors immediately after intervention or at the 6-month followup in either group [62]. A final study showed that the children who were in the behavioral modification treatment group reported greater TV viewing at every assessment point, compared with controls [63]. There did not appear to be any relationship between the number of behavior modification strategies used and the degree of reduction success.

Although some studies were successful at reducing sedentary screen behaviors among children, the reductions were highly variable. Also, the majority of studies did not find significant reductions in sedentary screen time. It is important to note that none of these studies had reducing sedentary screen time as the only primary dependent variable. Sixty-seven percent of these studies had changes in weight as the primary dependent variable, with changes in sedentary screen behaviors, physical activity, and diet as secondary dependent variables. The remaining 33% of these studies had multiple primary dependent variables (e.g., food and beverage consumption, physical activity, TV, sedentary screen time BMI, weight).

3.3.2. Interventions That Used Behavior Modification Plus Contingent TV. Contingent TV (where TV viewing is contingent upon performing certain tasks) has been used in three studies, in addition to behavior modification techniques, as a strategy to help reduce the amount of time children spend watching TV [50, 64, 65]. In these studies, children's targeted behaviors were rewarded by gaining access to TV, based upon completing certain tasks or for exercising for a certain amount of time [50, 64, 65]. One of the initial contingent TV studies [50] provided immediate access to TV viewing by having the child ride a stationary exercise bike attached to the TV (closed-loop system). The children could not watch TV unless they were pedaling the bike. This closed-loop system does not require any action by, or interaction with, another human. The system itself is set up to directly sense the output from the subject and then deliver the appropriate intervention or reinforcer [67]. More recent studies [64, 65] have used an open-loop system. In these studies, the open-loop system provides children the freedom to choose when they use the TV time they have earned as a result of performing a certain amount of physical activity [64, 65]. In addition to contingent TV, a total of four different behavior modification techniques were used to help the children reduce their sedentary screen behaviors: goal setting, positive reinforcement, problem solving, and self-monitoring. Positive reinforcement, with TV viewing serving as the reward, was the most frequently used behavior modification technique, followed by goal setting and self-monitoring. On average three behavior modification strategies were incorporated into the treatments of each of these studies. One study used four [64], one study used three [65], and one study used one behavior modification strategy [50].

Two contingent TV interventions reported significant reductions in TV viewing, which varied from 1.9 h/day [65] to 3.1 h/day [50], corresponding to a 72% [65] to 95% [50] reduction. In the third study, although the treatment group reduced TV viewing by 0.33 h/day, and the control group increased TV by 0.22 h/day, there was no significant difference in the changes between groups [64]. A contingent TV setup combined with behavior modification appeared to be a highly effective method to reduce TV viewing during the intervention.

4. Discussion

This paper demonstrates that various strategies can successfully reduce sedentary screen behaviors in children. Every identified study used behavior modification techniques. Thus, regardless of what theoretical framework was used for reducing sedentary screen behaviors, behavior modification strategies were always included in the intervention. The number of behavior modification strategies used to reduce sedentary screen behaviors varied from one to seven across these 18 studies. The more an intervention depended solely on behavior modification strategies to change sedentary screen behaviors, the greater the number of behavior modification strategies used. The behavior modification strategies cited most frequently were goal setting (78% of studies) and self-monitoring (67% of studies) of progress towards reducing sedentary screen behaviors. Preplanning, problem solving, and positive reinforcement were three additional behavior modification strategies used frequently. The nine studies that incorporated other methods (electronic TV monitoring devices or contingent TV devices) to elicit a reduction in sedentary screen behaviors used fewer behavior modification techniques. While the interventions that used electronic devices and contingent TV were the most effective in decreasing TV viewing time, these studies were shorter in duration and had smaller sample sizes. Slightly more than half of the studies focused on changing multiple behaviors. Most of these studies applied all the behavior modification strategies to all behaviors. A key challenge in reviewing the results of interventions that used multiple behavior modification techniques, even when only one behavior was being intervened upon, was to document and track the extent to which children utilized the specific behavior modification technique(s) that were provided and determine which technique(s) were most effective at creating behavior changes [62].

Individuals typically do not change their activities or behaviors when they are simply told to do so [68]. Interventions to reduce sedentary screen behaviors have used a number of theories and strategies for behavior change. Most studies reported having a theoretical foundation. Two of the key theoretical approaches, social cognitive theory [69] and behavioral choice theory [70, 71], were used in 44% of the studies. These theories share the belief that behaviors may be learned from observing others and that changes in behaviors may be mediated or moderated by a number of individual, social, and environmental factors. Several other studies were based on the reinforcement theory known as the Premack principle [67]. These interventions used the reinforcing value of a popular, highly rated behavior such as watching TV to increase physical activity and reduce sedentary screen behavior by making TV contingent on physical activity. The stages of change theory, that is, the transtheoretical models' stages of change [72] were used in one study to assess the caregiver's readiness to act on new health behaviors as it related to their child. Caregivers were guided thru the stages so that they might engage in strategies that would assist their child in making changes.

As a whole, most of the studies were conducted with preadolescent children, with the ages of 8 to 12 years the most highly represented. Slightly more than half of the studies were conducted in research settings, and over 70% of the interventions were delivered to both the children and the parents. Thus, it is not clear how effective these interventions are for adolescents, if targeting the parent alone in children aged 1 to 12, or delivery of the intervention from nonresearch settings would improve these outcomes.

Interestingly, two interventions which demonstrated negative results and showed an increase in sedentary screen behaviors [62, 63] targeted children in the oldest age group (8–12 years), focused on changing multiple health-related behaviors, and relied on behavior modification techniques alone, and although they made efforts to engage parents, there was no requirement for or assessment of actual parental engagement.

Additionally, one of the studies that showed negative outcomes was a multilevel intervention that was delivered through community media campaigns, mass mailings of newsletters to parents, and an optionally incorporated school curriculum [62]. The large-scale delivery of multiple health behavior messages may have diluted the message of reducing sedentary screen behaviors [62]. The other intervention that had an undesirable effect was a school-based program designed to reduce sedentary screen behaviors and increase physical activity. Parental involvement was solicited through a newsletter [63].

Another important difference between the investigations was methods used to assess sedentary screen behavior. Most investigations relied on self-report for assessing sedentary screen behaviors. Self-report (child only, parent only, and parent-assisted, or parent and child) of sedentary screen behaviors was the method used most frequently (89%) to measure changes. In 44% of the studies, the children were considered responsible/old enough (ages 8–12 years) to report themselves, and 45% used some form of parental, parent and child, or parent-assisted report. In general, studies assessing sedentary screen behaviors in younger children were more likely to rely on parental report or parent-assisted child report. Use of self-report surveys reduces researcher and participant burden because it is easy, less expensive, and less invasive or intrusive than placing an electronic monitoring device on all screen devices in the home. Although self-report and parental-report measures of sedentary screen behavior are commonly used, research regarding their validity and reliability is lacking [73]. The validity and the sensitivity of the different questionnaires to detect change in television viewing habits may vary by the age of the child and whether the parent or the child does the reporting [51]. Measuring sedentary screen behaviors via self-report is prone to reporting and measurement bias [57]. In households where TV provides background noise to daily activities, parent or child perceptions of "watching time" could be different [74]. In intervention studies focused on reducing TV viewing, the perception of TV being a negative behavior could cause an underreporting of viewing [74].

TV time monitors that can provide objective measures of viewing time may be suitable for some interventions [53], but using objective measurement methods may limit the number of sedentary screen behaviors capable of being monitored. Objective measures of TV watching were used less frequently (11%) than self-report and were used in studies with smaller sample sizes ($N = 10$ and $N = 70$).

The commonality in the investigations that found the largest reductions in sedentary screen time was use of electronic devices or making TV contingent on other behaviors [49, 50, 53, 56, 65]. To date, trials using TV time monitoring, mandatory TV devices, or contingent TV suggest reductions in TV watching of 30–90% are possible. Creating family rules that limit television viewing could have similar effects, but notable differences may exist in the child's perception of control when comparing the use of technology versus parental control. The behavioral engineering technology of the TV Allowance appears to simplify the modification of child television viewing. It puts the choice of when to watch television in the child's control, as opposed to having a rule such as no television time until homework is completed. Because the device is enforcing the TV limits, it may also eliminate conflicts between parents and children and reduce the need for disciplinary action if a child exceeds his/her TV viewing time limit [53]. However, there are some important factors to consider with these types of interventions, and further robust investigation of the long-term effectiveness and sustainability of electronic TV time monitors is necessary [57]. In regards to the devices that limited the hours of TV watching, it is not clear whether, or for how long, a reduction in TV watching will remain when these devices are removed.

In reference to contingent TV studies, using TV as a reward for physical activity seems problematic and counter-intuitive if reducing sedentary screen behavior is the goal.

Using something (i.e., TV) as a reward may contribute to the increased liking of it and actually increase its reinforcing value [75]. Rewarded behaviors are likely to be repeated, but there is little evidence that these techniques promote long-term behavior change [76]. Furthermore, there seems to be no positive outcome for promoting TV watching, so making this more reinforcing may create additional problems in the future. Also it is unknown whether the reduction in sedentary screen behaviors could have occurred without linking TV viewing to physical activity. Longer follow-up periods are needed for studies that involved contingent TV and mandatory use of an electronic TV monitoring device. Only four of the 18 interventions reevaluated the magnitude of sedentary screen behavior changes in the follow-up period after the intervention had been completed. Without follow-up data, the long-term sustainability of reduced sedentary screen behaviors remains questionable.

Limitations in intervention design, implementation, research design, effect moderation, target outcome, and measurement issues are all variables that could impact the success of behavior modification interventions. Very few studies reported on the fidelity of intervention delivery or receipt making it challenging to ascertain the validity of behavioral outcomes reported. These issues may compromise the internal validity of an intervention. Thus, the lack of information on fidelity of intervention delivery, and/or receipt, and the variations among studies make comparing study efficacy challenging. Additionally, many different assessment tools were used in these studies to document changes in sedentary screen behaviors. Most specifically, the difference between self-report versus objective measures makes comparing outcomes between the studies challenging. Finally, several of the studies included in this paper had small sample sizes, which potentially minimized power to find significant outcomes, and/or were of short duration, with minimal followup.

While reducing sedentary screen behaviors may have a positive impact on improving the health of children, this paper highlights the need for future research in this area. Interventions to reduce sedentary screen time need to be explored further with different age groups (children less than 6 years old, teenagers, and adults) and in various different delivery settings (pediatrician offices, schools, after-school programs, communities, etc.). As new screen options continuously emerge (smart phones, ipads, etc.), it will be necessary to conduct comprehensive research that targets these other sedentary screen options. It is imperative that reliable and valid measurements of screen behaviors are developed and that measure all important sedentary screen time options. Finally, as screen-based behaviors appear to play a more prominent role in American's leisure time, reducing sedentary screen time alone may not be enough. Research needs to investigate ways to make sedentary screen behaviors more active.

In summary, interventions with an emphasis on reducing sedentary screen behaviors have been successful in preadolescent children. The magnitude of the significant sedentary screen behavior reductions varied greatly (-0.44 h/day to -3.1 h/day). Importantly, the most effective interventions for reducing sedentary screen behaviors in children focused exclusively on sedentary screen behaviors or involved tools beyond the use of behavior modification techniques. Results from these interventions also suggest that behavioral modification strategies alone may be less effective at reducing sedentary screen behaviors when sedentary screen behaviors are one of multiple health-related behaviors of interest and when sedentary screen behaviors are not the primary outcome of interest. Focusing on multiple health behaviors at once may dilute the outcomes of specific health behaviors. In several of the studies that targeted multiple health-related behaviors, sedentary screen behaviors increased or were not affected at all. Based on the results of this paper, there is a need for future research to better understand methods to more effectively reduce sedentary screen time in children.

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