Published in final edited form as:

Med Sci Sports Exerc. 2012 June ; 44(6): 1075–1080. doi:10.1249/MSS.0b013e318245ca20.

Breaks in Sedentary Time during Childhood and Adolescence: Iowa Bone Development Study

Soyang Kwon¹, Trudy L. Burns^{2,3}, Steven M. Levy^{4,2}, and Kathleen F. Janz^{5,2}

¹Consortium to Lower Obesity in Chicago Children, Children's Memorial Hospital, Chicago, IL

²Department of Epidemiology, University of Iowa, Iowa City, IA, USA

³Department of Pediatrics, University of Iowa, Iowa City, IA, USA

⁴Department of Preventive and Community Dentistry, University of Iowa, Iowa City, IA, USA

⁵Department of Health and Human Physiology, University of Iowa, Iowa City, IA, USA

Abstract

Purpose—The frequency of interruptions in sedentary time (sedentary breaks) is an aspect of sedentary behaviors which may be associated with metabolic health outcomes. The aim of this study was to describe the change in the frequency of sedentary breaks over a 10-year period from ages 5 to 15.

Methods—The longitudinal Iowa Bone Development Study has collected accelerometry data at approximately 5, 8, 11, 13, and 15 years of age. Data from participants who wore an accelerometer at least 10 hours per day and three days per data collection episode were used (423 children at age 5, 550 at age 8, 520 at age 11, 454 at age 13, and 344 at age 15). The frequency of sedentary breaks was determined based on accelerometry data and compared by weekday/weekend, time period during the day, gender, and data collection episode.

Results—The frequency of sedentary breaks decreased by > 200 times/day over a 10-year period from ages 5 to 15. Linear regression models estimated a 1.84 times/hour decrease per year for boys and a 2.04 times/hour decrease per year for girls ($P_s < 0.0001$). Both boys and girls showed significantly fewer breaks on weekdays from morning to 3:00 PM than on weekends from morning to 3:00 PM ($P_s < 0.0001$). The frequency of sedentary breaks was slightly higher among boys than girls (gender difference = 2 times/hour; $P_s < 0.01$ at ages 11, 13, and 15).

Conclusion—Breaks in sedentary time notably decrease during childhood and adolescence. During school hours, boys and girls have fewer breaks in sedentary time than during any other time period of weekday or weekend day.

Keywords

physical activity; sedentary behavior; inactivity; accelerometer; cohort study

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Corresponding author: Soyang Kwon, 2300 Children's Plaza Box #157, Chicago, IL 60614, Office phone: 1-312-573-7764; Office Fax: 1-312-573-7825; skwon@childrensmemorial.org.

Conflict of interest: none declared for each author

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INTRODUCTION

Except for adults aged 60 years or older, adolescents (age 12 to 18 years) are the age group that spends the greatest amount of hours in sedentary behaviors (12). Within this age group, adolescent girls spend more time in sedentary behaviors than boys. The potential health risk of sedentary behaviors has recently been acknowledged (15). The patterns by which the sedentary time is accrued may also play an important role in body fat accumulation and metabolic health. Three cross-sectional adult studies (1, 4, 5) have shown that the frequency of interruptions in sedentary time (hereafter ‘sedentary breaks’) is inversely associated with waist circumference, body mass index, C-reactive protein, fasting plasma glucose levels, and prevalence of the metabolic syndrome. However, to our knowledge, no study exists to examine the frequency of sedentary breaks in children and adolescents. In particular, longitudinal changes in the frequency of sedentary breaks have not been described. In this study, we describe the change in the frequency of sedentary breaks over a 10-year period during childhood and early adolescence. We also compare the frequency between weekdays and weekend days. This study lays the foundation to begin to understand changes in patterns of sedentary behaviors during childhood and adolescence and to identify the potential effects of sedentary breaks on health outcomes among children and adolescents.

METHODS

Participants

The Iowa Bone Development Study (IBDS) is an ongoing longitudinal study of bone health during childhood and adolescence. During 1998 to 2002, the IBDS recruited children at age 5 from the Iowa Fluoride Study population. The Iowa Fluoride Study originally recruited 1,882 families of new-born babies from eight Iowa hospital postpartum wards from 1992 to 1995 (11). Approximately 95% of participants were white. Additional information about the study design and demographic characteristics of participants can be found in previous publications (6-9). The current analysis focused on data collected at approximately 5, 8, 11, 13, and 15 years of age (labeled Waves 1 to 5) during 1998 to 2009. Among children who were contacted and responded to a study invitation letter at Wave 1, 455 of 478 consented to wear an accelerometer, as did 584 out of 605 at Wave 2, 553 out of 581 at Wave 3, 504 out of 538 at Wave 4, and 455 out of 491 at Wave 5. The study was approved by the University of Iowa Institutional Review Board (Human Subjects). Written informed consent was provided by the parents of the children. Assent was obtained from the children.

Data collection

The detailed procedure for accelerometer data collection has been described in previous publications (6-9). During an initial study visit, research nurses trained in anthropometry measured the child’s height and weight. Children and their parents were also given instruction on accelerometer wear. Actigraph uniaxial accelerometers (model number 7164, Pensacola, FL; GT1M for Wave 5 only) were sent to eligible participants via pre-paid mail during the fall season (September to November). Children were asked to wear the monitor during waking hours for four consecutive days, including one weekend day, at Waves 1 and 2, and for five consecutive days, including both weekend days, at the other Waves. At Wave 5, a relatively higher proportion of participants wore the monitor for less than four days, compared to previous waves. Therefore, those participants were asked to re-wear the monitor for another five days and data collection was extended until mid-December. Mid-December weather is similar to mid- to late-November weather in Iowa. Accelerometer movement counts were collected in one-minute epochs at Waves 1 to 4 and five-second epochs at Wave 5. Wave 5 data were re-integrated to one minute.

Accelerometer data reduction and processing

Accelerometers were considered as not worn if a period of 60 consecutive minutes of zero accelerometer counts with allowance for two non-zero interruptions was encountered in the accelerometer data array (3). We only used accelerometer data from participants who wore an accelerometer for a minimum of 10 hours per day and three days per wave (13). We identified 423, 550, 520, 454, and 344 individuals at Waves 1 to 5, respectively, who met the inclusion criteria. Two hundred twenty-three participants had complete accelerometer data for all five waves; 174 for four waves; 101 for three waves; 62 for two waves; and 53 for one wave (a total of 613 individuals). Five individuals who re-wore the accelerometer in December for Wave 5 met the inclusion criteria.

Sedentary time was considered to be interrupted or broken if accelerometer counts were 100 counts per minute (4). The number of interruptions was counted as *daily frequency of sedentary breaks* (times/day). Moderate- to vigorous-intensity was defined as 2,296 or greater accelerometer counts per minute (2, 16). Accelerometer data were also organized by type of day (weekday and weekend day) and the following time periods of day: monitor-on (morning) to 3:00 PM, 3:00 PM to 7:00 PM, and 7:00 PM to monitor-off (sleep).

Statistical analysis

Age was calculated by subtracting date of birth from date of accelerometer measurement. The *hourly frequency of sedentary breaks* (times/hour) was calculated by dividing daily frequency of sedentary breaks into daily wear time in hours for each wear day. Means of daily and hourly frequency of sedentary breaks per individual across the day of wear were calculated at each wave.

Descriptive analyses were conducted. Intraclass correlation coefficients (ICCs) for repeated measures of the mean hourly frequency of sedentary breaks and MVPA time were estimated in a multilevel model without predictors. Pearson correlation coefficients were estimated by sex and wave between the mean daily frequency of sedentary breaks and the mean daily MVPA time, as well as the mean daily sedentary time. To obtain aggregated correlation coefficients, the covariance correlation between the mean daily frequency of sedentary breaks and the mean daily MVPA time was calculated in a multilevel model.

Because a decreasing trend in the mean frequency of sedentary breaks over time was identified in descriptive analysis, the yearly decrease in the mean hourly frequency of sedentary breaks was estimated using linear regression models. An age $\times$ sex interaction effect was significant ($P < 0.05$); therefore, sex-specific regression models were fitted (independent variable: age, dependent variable: the mean hourly frequency of sedentary breaks). To compare the hourly frequency of sedentary breaks between weekdays and weekend days, sex- and wave-specific multilevel models were built (fixed effect: age and type of the day, random effect: within-subject repeated measures for three or more days of monitor-wear, dependent variable: the hourly frequency of sedentary breaks). Because between-within interaction effects were not statistically significant, the interaction term was not included in the final models. Another set of multilevel models was built according to time periods during the day. Matrix structure type was determined based on Akaike's Information Criterion (AIC) for goodness of fit. Residual and studentized residual graphs were used to confirm model assumptions and fit.

In exploratory work, we repeated analyses for a cohort of 223 individuals who had sedentary break data at all five waves (the "closed" cohort). In addition, we examined the tracking of frequency of sedentary breaks in the closed cohort, using Pearson correlation coefficients. All analyses were conducted using SAS version 9.2 (Cary, NC).

RESULTS

Table 1 presents the characteristics of participants. The mean daily frequency of sedentary breaks decreased > 200 times over a 10-year period from age 5 to age 15 in both boys and girls. The mean daily sedentary time increased by approximately 4.5 hours. The mean MVPA time was the highest at age 11 among boys, while it decreased over time among girls. The ICC for the mean hourly frequency of sedentary breaks was estimated as 0.06, whereas the ICC for the mean MVPA time was 0.39. Gender differences in the mean hourly frequency of sedentary breaks were within 2 times/hour at each wave, with fewer breaks among girls than boys (P s < 0.01 at Waves 3, 4, and 5). The slope from a fitted linear regression model estimated a 1.84 times/hour decrease in sedentary breaks per year for boys ($R^2=0.60$) and a 2.04 times/hour decrease per year for girls ($R^2=0.66$; P s < 0.0001).

As shown in Figure 1, there was a positive association between mean daily frequency of sedentary breaks and mean MVPA time (covariance correlation = 0.52). However, the mean daily frequency of sedentary breaks was widely distributed, particularly at low MVPA count levels. For each of Waves 1 to 5, Pearson correlation coefficients of mean daily frequency of sedentary breaks and mean daily MVPA time were 0.41, 0.48, 0.60, 0.55, and 0.58, respectively, for boys, and 0.54, 0.43, 0.52, 0.46, and 0.50, respectively, for girls (all P s < 0.001). Wave-specific Pearson correlation coefficients of mean daily frequency of sedentary breaks and mean daily sedentary time were -0.71, -0.79, -0.74, -0.75, and -0.64, respectively, for boys, and -0.71, -0.78, -0.74, -0.64, and -0.55, respectively, for girls (all P s < 0.0001).

Figure 2 presents the mean hourly frequency of sedentary breaks over time periods during the day by wave (age). In all waves, there was a pattern that the number of sedentary breaks was the lowest during morning to 3:00 PM and the highest from 3:00 to 7:00 PM.

As illustrated in Figure 3.a, boys and girls more frequently broke up their sedentary time on weekend days when compared to weekdays. When sorted by time periods during the day, boys and girls had significantly fewer sedentary breaks on weekdays from morning to 3:00 PM, compared to weekends from morning to 3:00 PM (Figure 3.b); the difference was 6 times/hour at all waves (P s < 0.0001), except for Wave 1 when the difference was 4 times/hour (P s < 0.0001). From 3:00 PM to 7:00 PM, the hourly frequency of sedentary breaks was not different between the weekdays and weekend days at Waves 1 through 3 (Figure 3.c). However, both boys and girls had fewer sedentary breaks at Waves 4 and 5 on weekend days when compared to weekdays (P s < 0.0001). After 7:00 PM, both boys and girls had slightly fewer sedentary breaks on weekends when compared to weekdays (P s < 0.05; Figure 3.d).

The trend for a decreasing frequency of sedentary breaks over time was also observed in the closed cohort of 223 individuals (P s from linear regression estimates < 0.0001). Wave-specific means and standard deviations of the mean hourly frequency of sedentary breaks were 43 ± 4 , 38 ± 4 , 35 ± 5 , 32 ± 5 , and 24 ± 4 times/hour, respectively, for 108 boys, and 42 ± 4 , 37 ± 4 , 34 ± 5 , 29 ± 5 , and 22 ± 4 times/hour, respectively, for 115 girls. As presented in Table 2, tracking of the mean hourly frequency of sedentary breaks for 2 to 3 years was moderate (P s < 0.001).

DISCUSSION

This is the first study demonstrating a notable decrease in the frequency of sedentary breaks during childhood and adolescence. Boys and girls have fewer sedentary breaks during school hours than during non-school hours or weekend. Overall, gender differences in the frequency of sedentary breaks were minimal; although in general girls took slightly fewer

breaks than boys. We found a moderate association between sedentary breaks and MVPA. However, the frequency of sedentary breaks varied widely for children with low levels of MVPA. The frequency of sedentary breaks was strongly and inversely associated with sedentary time. Finally, the tracking of the frequency of sedentary breaks for 2 to 3 year intervals during childhood and early adolescence was moderate, whereas the tracking over a 10-year interval was low.

Healy et al. (4) reported the first study to examine sedentary breaks among Australian adults, where the mean total number of sedentary breaks was 601 times during the mean total sedentary time of 56.7 hours. In another study by Healy et al. (5), the average frequency of daily sedentary breaks was 90 times/day among men (mean wear time: 14.9 hours/day) and 95 times/day among women (mean wear time: 14.4 hours/day) participating in the 2003-2006 NHANES. It appears that adults have considerably fewer sedentary breaks than the IBDS cohort members. This comparison may reflect the different social circumstances and life style choices throughout the life cycle. Children's activity patterns are more sporadic and spontaneous. As they enter adolescence, they are involved in longer sitting activities in the classroom and during leisure time (e.g., computer use). The life style of adults often involves continuous and prolonged sedentary behaviors at work and during leisure time. Gender differences seem to be minimal, although they should be further verified by data from diverse populations.

Repeated measures of the frequency of sedentary breaks over a 10-year period were weakly correlated when compared to repeated measures of MVPA time. This finding suggests that sedentary break behaviors may be less stable than MVPA behaviors during childhood and early adolescence. The tracking of sedentary breaks over a 10-year period was low. This is advantageous for intervention programs aimed at decreasing prolonged inactivity since our findings suggest a behavior that is changeable.

The frequency of sedentary breaks was strongly and inversely associated with sedentary time. This implies an increased engagement in prolonged sedentary behaviors, such as TV viewing or computer use, as children grow into adolescence. There are increased expectations within the schools that children spend prolonged time on tasks as they advance through grades. Interventions which simply focus on breaking prolonged sedentary time might be successful in reducing total sedentary time. A great deal of variability in the frequency of sedentary breaks within a low level of MVPA suggests the potential independence of MVPA and sedentary break behaviors among those who have low MVPA levels. This finding indirectly suggests that light activity such as sedentary breaks may be particularly important and effective to adolescents who engage in low MVPA.

Although we found that sedentary breaks were significantly fewer (approximately 6 times/hour) on weekdays from morning to 3:00 PM (school hours) than weekend days from morning to 3:00 PM, no evidence exists on whether the magnitude of the difference is meaningful with respect to health risk. Future research is recommended to investigate the effects of sedentary breaks on various health outcomes, particularly adiposity, among adolescents. If health effects of sedentary breaks are proven, schools may be a potential intervention setting for increasing the frequency of sedentary breaks. School policy interventions such as increasing recess time and activity breaks during class time (14) may have an impact on students' sedentary break behaviors. Interventions in the school setting may provide additional benefits in academic performance and morale.

The main limitation of this study is the threat of selection bias. We included participants who completed at least one of five assessments (open cohort). Loss to follow-up may have caused selection bias. Our cohort study experienced significant attrition particularly at age

15. However, analyses for the closed cohort revealed that the patterns of sedentary breaks were similar to the open cohort. Sedentary break behaviors may be influenced by maturation and socio-psychological changes during adolescence, which the current study did not take into account. The frequency in sedentary breaks may differ by season and therefore, our data collected in the fall season may not represent the mean annual frequency. The frequency in sedentary breaks may differ by season and therefore, our data collected in the fall season may not represent the mean annual frequency. However, the repeated measurements during the same season would have minimized bias by seasonal variation within a year. This is particularly important given our cohort is mainly in the Midwest which has dramatically different weather patterns across seasons. The accelerometry output may differ between Actigraph model 7164 and GT1M: greater variability in the model 7164 with analog circuit filtering system than GT1M with digital filtering system. We calibrated all the model 7164 accelerometers with a shaker, prior to sending out to participants. Also, it has been reported that the difference is random and data with the GM1 are comparable with the model 7164 when summarizing data using cut-point methods (10). Because of the geographical location of the IBDS, most participants are white. Therefore, caution should be taken in generalizing the results to diverse populations in other geographical locations.

Nonetheless, this study is innovative as a first longitudinal investigation of sedentary breaks during childhood and adolescence. Five assessments over a 10-year period allowed demonstration of the change in sedentary breaks throughout childhood and early adolescence. This study would provide a new venue for research on the roles of sedentary behaviors in childhood obesity and health.

In conclusion, this study demonstrates that the frequency of sedentary breaks notably decreases over childhood and adolescence. Boys and girls have fewer sedentary breaks during school hours than during after-school hours or during the weekends.

Acknowledgments

This study was supported by the National Institute of Dental and Craniofacial Research R01-DE12101 and R01-DE09551, and the General Clinical Research Centers Program from the National Center for Research Resources, M01-RR00059. The authors have no conflicts of interests to report.

The results of the present study do not constitute endorsement by the American College of Sports Medicine.

Funding: This study was supported by the National Institute of Dental and Craniofacial Research R01-DE12101 and R01-DE09551, and the General Clinical Research Centers Program from the National Center for Research Resources, M01-RR00059.

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Figure 1.

Scatter plot of the mean daily minutes spent in moderate- to vigorous-intensity physical activity and the mean daily frequency of sedentary breaks over all waves

Note. MVPA time, minutes spent in moderate- to vigorous-intensity physical activity. An estimated covariance correlation between the mean daily frequency of sedentary breaks and the mean daily minutes spent in moderate- to vigorous-intensity physical activity was 0.52.

Figure 2.
Means and 95% confidence intervals of the mean hourly frequency of sedentary breaks over time periods of the day by age

a

b

Figure 3.
Change in the hourly frequency of sedentary breaks over a 10-year period from ages 5 to 15 years

a. Whole waking hours	b. Morning to 3:00 PM
c. 3:00 to 7:00 PM	d. 7:00 PM to sleep

Table 1

Participant characteristics by gender and waves

	Boys					Girls				
	Wave1 (n=201)	Wave2 (n=270)	Wave3 (n=259)	Wave4 (n=229)	Wave5 (n=175)	Wave1 (n=222)	Wave2 (n=280)	Wave3 (n=261)	Wave4 (n=225)	Wave5 (n=169)
Age (years)	5.7 ± 0.6	8.8 ± 0.7	11.1 ± 0.4	13.0 ± 0.3	15.0 ± 0.3	5.7 ± 0.5	8.8 ± 0.6	11.1 ± 0.3	13.1 ± 0.3	15.0 ± 0.3
Height (cm)	112 ± 6	135 ± 7	149 ± 8	163 ± 10	175 ± 8	111 ± 5	133 ± 7	149 ± 7	161 ± 7	164 ± 7
Weight (kg)	20.4 ± 3.8	33.7 ± 9.6	45.4 ± 13.2	58.0 ± 16.1	69.7 ± 16.7	20.0 ± 3.8	31.8 ± 8.5	44.5 ± 12.4	55.6 ± 14.3	61.6 ± 14.5
Accelerometer-wear days (days)	3.9 ± 0.4	3.9 ± 0.4	4.7 ± 0.7	4.6 ± 0.8	4.1 ± 0.9	3.9 ± 0.4	3.9 ± 0.4	4.7 ± 0.6	4.5 ± 0.9	4.1 ± 1.0
Weekday wear time (hours/day)	12.4 ± 1.0	12.7 ± 1.1	12.8 ± 1.2	13.0 ± 1.4	13.3 ± 1.6	12.4 ± 1.0	12.7 ± 1.0	12.8 ± 1.2	13.1 ± 1.5	13.2 ± 1.7
Weekend day wear time (hours/day)	12.0 ± 1.1	12.2 ± 1.2	12.2 ± 1.2	12.1 ± 1.3	12.2 ± 1.5	12.1 ± 1.2	12.0 ± 1.2	12.1 ± 1.2	12.2 ± 1.3	12.2 ± 1.5
Weekday sedentary breaks (times/day)	525 ± 73	464 ± 87	436 ± 88	390 ± 93	308 ± 84	519 ± 75	456 ± 83	412 ± 89	370 ± 97	285 ± 83
Weekend day sedentary breaks (times/day)	532 ± 83	486 ± 93	449 ± 99	392 ± 107	320 ± 97	525 ± 89	474 ± 88	437 ± 94	370 ± 96	289 ± 92
Sedentary time (hours/day)	3.6 ± 0.8	4.8 ± 0.9	5.4 ± 1.0	6.4 ± 1.2	8.1 ± 1.0	3.7 ± 0.8	4.9 ± 0.9	5.6 ± 1.1	6.8 ± 1.1	8.4 ± 1.0
MVPA time (minutes/day)	60.9 ± 23.8	64.6 ± 28.6	64.3 ± 28.9	52.2 ± 24.7	40.6 ± 20.7	47.7 ± 19.7	46.3 ± 21.0	39.8 ± 19.2	34.1 ± 19.9	28.3 ± 18.4
MVPA, moderate- to vigorous-intensity physical activity										

Tracking coefficients (*r*) for the mean hourly frequency of sedentary breaks in a closed cohort of 223 participants

Table 2

	Waves 1 & 2	Waves 2 & 3	Waves 3 & 4	Waves 4 & 5	Waves 1 & 3	Waves 1 & 4	Waves 1 & 5
Boys (n=108)	0.43**	0.43**	0.45**	0.45**	0.30*	0.32**	0.25*
Girls (n=115)	0.40**	0.49**	0.52**	0.43**	0.43*	0.20	0.25*

Pearson correlation coefficients.

* $P<0.01$

** $P<0.001$.