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PEDIATRIC ORIGINAL ARTICLE

Association between objectively measured sedentary behavior and body mass index in preschool children

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OBJECTIVE: To determine the association between accelerometry-derived sedentary behavior and body mass index (BMI) *z*-score in preschool children, and to determine whether the association changed when applying three different accelerometry cutpoints for sedentary behavior.

DESIGN AND SUBJECTS: Cross-sectional design. Data came from two completed studies: Children's Activity and Movement in Preschool Study (CHAMPS) and the Environmental Determinants of Physical Activity in Preschool Children (EDPAPC) study. Children of ages 3–5 years with complete data on sedentary behavior, BMI *z*-score, physical activity and other covariates were included in the analyses ($N = 263$ in CHAMPS and $N = 155$ in EDPAPC). Accelerometry data were summarized as time spent in sedentary behavior (min h^{-1}) using three different cutpoints developed specifically for preschool children (<37.5, <200 and <373 counts per 15 s). Linear mixed regression models were used to determine the association between time spent in sedentary behavior and BMI *z*-score; age, gender, race, parental education, preschools and moderate-to-vigorous physical activity (MVPA) were included as covariates.

RESULTS: In both CHAMPS and EDPAPC studies, no independent association between time spent in sedentary behavior and BMI *z*-score was observed after adjusting for MVPA. The observed null association between sedentary behavior and BMI *z*-score was maintained even with different sedentary behavior cutpoints.

CONCLUSIONS: Regardless of cutpoints used, accelerometry-derived sedentary behavior was not independently associated with BMI *z*-score in two independent samples of preschool children. Longitudinal studies addressing this research question are needed.

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Keywords: accelerometer; preschool; sedentary behavior; BMI

INTRODUCTION

The prevalence of pediatric obesity has increased dramatically in recent decades,[1,2] and this trend also has been observed in preschool children (ages 3–5 years).[3] Reversing the childhood obesity epidemic has become urgent public health priorities, as childhood and adult obesity are strongly linked.[4] In considering modifiable risk factors associated with childhood obesity, it has been hypothesized that sedentary behavior is independently associated with the increased risk of childhood obesity.[5,6]

Cross-sectional and longitudinal studies have reported that sedentary behavior is a risk factor for overweight and obesity in preschool children.[7–11] In those studies, however, sedentary behavior was measured using proxy reports (that is, parent-reported time spent watching television and playing video games), and the potential influence of children's physical activity on the association between sedentary behavior and obesity was not taken into account. Studies that have examined the relationship between objectively measured sedentary behavior and obesity in preschool children are very limited,[12] and no previous study has investigated the association between accelerometry-derived sedentary behavior and obesity in preschool children, adjusting for time spent in moderate-to-vigorous physical activity (MVPA).

Accelerometry is a known objective measure of sedentary behavior in preschool children.[13–17] To date, studies have used several accelerometry cutpoints to estimate sedentary behavior in preschool-age children; these include <37.5 counts per 15 s,[18] <200 counts per 15 s,[18] <373 counts per 15 s[19] and <1100 counts per 60 s.[20] Depending on the cutpoints used, the estimates of accelerometry-derived time spent in sedentary behavior can vary considerably (for example, 343.2–617.6 min per day).[19,21] Therefore, it is possible that the association between sedentary behavior and health outcomes of interest could be influenced by the cutpoint applied.

The primary purpose of this study was to determine the independent association between accelerometry-derived sedentary behavior and body mass index (BMI) *z*-score in a cross-sectional sample of preschool children enrolled in two existing studies. A secondary purpose was to determine whether the association was similar when three different accelerometry cutpoints for sedentary behavior were applied.

MATERIALS AND METHODS

Study design

The aims of this study were addressed using two existing cross-sectional data sets, The Children's Activity and Movement in Preschool Study (CHAMPS) and the Environmental Determinants of Physical Activity in Preschool Children (EDPAPC) study. Full details regarding the design of each study are reported elsewhere.[22,23] In brief, both CHAMPS and the EDPAPC study collected activity data in preschool children over a 2-week

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period. In CHAMPS, children's total-day activity (in-school and out-of-school) was measured, but only in-school activity data were collected in the EDPAPC study. It has been suggested that at least 2 days or 6 days of accelerometry monitoring are required to reliably measure (intraclass correlations $\geqslant 0.80$) school-day or total-day sedentary behavior in preschool children, respectively.[24] For the analyses in the current study, we included children who had at least 3 days of in-school sedentary behavior data in the EDPAPC study, and at least 6 days of total-day sedentary behavior data in CHAMPS.

Participants

The participants in this study were preschool children, aged 3–5 years, who were enrolled in the CHAMPS[22] and EDPAPC study.[23] In both studies, all preschools with an enrollment of 60 or more children in the greater Columbia, South Carolina area were identified. The preschools were stratified into one of three types: head start, private and religious. After random selection from each stratum (school type), 22 preschools and 9 preschools were recruited in CHAMPS and EDPAPC study, respectively. The number of participants per preschool ranged from 14–33 in CHAMPS, and from 22–30 in EDPAPC. The participants in both studies were from diverse sociodemographic backgrounds, and the race/ethnicity distribution of participants reflected that of the population in the greater Columbia area.[25] A total of 263 children (51% girls, 51% Black) from CHAMPS, and 155 children (49% girls, 55% Black) from EDPAPC were available for the present analyses after excluding children with missing data on the study variables ($\approx$38% in CHAMPS and $\approx$41% in EDPAPC). The distributions of age, gender, race, BMI and parent education level were not different between children who were included and excluded. Written informed consent was obtained from the children's parents or guardians prior to collection of data. Both studies were approved by the Institutional Review Board at the University of South Carolina.

Assessment of sedentary behavior

In both studies, sedentary behavior was measured using ActiGraph accelerometers (ActiGraph model 7164, Shalimar, FL, USA). In order to capture the spontaneous activities of 3- to 5-year-old children, the accelerometers were initialized to save data in 15-sec intervals (epochs). Each child was instructed to wear the accelerometer on an elastic belt on the right hip. In CHAMPS, participants wore the accelerometer for the total day (during and after school hours). The parents of CHAMPS participants received information about the accelerometer, and instructions on how their child should wear the monitor over a 2-week period. Unlike CHAMPS, the participants in the EDPAPC study wore the accelerometer for the duration of his/her stay at the preschool (at least 6 h) during a 2-week period. Accelerometers were placed when children arrived at preschool and were removed right before children left for the day. All the preschools included in this study scheduled a nap during each day ($\approx$1 h), and children wore accelerometers during nap time. As all the children were required to be sedentary during this period, nap time was included in the total wear time.

Accelerometry data reduction

The accelerometer-count data were reduced using three different activity intensity cutpoints developed specifically for 3- to 5-year-old children. The sedentary behavior cutpoints used were <37.5,[18] <200 [18] and <373 counts per 15 s.[19] The cutpoint for MVPA was $\geqslant 420$ counts per 15 s.[18] Using each child's wear time as the divisor, cumulative time spent in sedentary behavior and MVPA was averaged on an hourly basis (min h^{-1}) to take into account differences in the monitoring time of children on a given day. Sixty minutes of consecutive zeros was considered as non-wear time. In both CHAMPS and EDPAPC, days that children were absent from preschool and on which total wear time was $\geqslant$18 h (that is, monitor malfunction) or $<$6 h were excluded from the analysis because those days do not represent typical days.

Demographic characteristics

In both CHAMPS and EDPAPC, children's age, gender, race/ethnicity and socioeconomic status (parental education level) were reported by a parent or guardian using a self-administered parent survey.

Anthropometry and BMI *z*-score

In both studies, weight was measured to the nearest 0.1 kg using an electronic scale, and height was measured to the nearest 1 mm using a stadiometer, after the child removed shoes and outer clothing. The average of two measurements was used to determine height and weight. BMI was calculated as weight divided by height squared (kg m^{-2}). BMI *z*-score was calculated by assessing the deviation of each child's BMI value from the population mean BMI values reported in the CDC growth charts.[26]

Statistical analyses

Descriptive statistics for the participants were calculated, using means and s.d.'s for continuous variables, and frequencies and percent for categorical variables. Simple *t*-tests and χ^2 tests of independence were used to examine differences in age, gender, race, parent education level, BMI, BMI *z*-score and accelerometry wear time between participants in CHAMPS and EDPAPC. Gender differences in the amount of time spent in sedentary behavior were examined using independent sample *t*-tests.

Mixed linear regressions (PROC MIXED procedure in SAS) were used to determine the association between accelerometry-derived sedentary behavior and BMI *z*-score. BMI *z*-score was regressed on time spent in sedentary behavior (min h^{-1}) for each of the three sedentary behavior estimates. To take into account the correlation among children from the same preschool, the models included preschool as a random effect. Sociodemographic factors such as age, gender, race and parent education level were included as covariates in the mixed models (Model 1). The levels of MVPA (min h^{-1}) were additionally adjusted to fully determine the independent association between sedentary behavior and BMI *z*-score in mixed models (Model 2) due to significant relationships of MVPA with adiposity in preschoolers.[27–29] Interaction terms between sedentary behavior and sociodemographic factors also were included in the mixed models (Model 1 and 2). If there was statistical evidence of interactions, we performed the stratified analyses to determine if the association between sedentary behavior and BMI *z*-score differed by these sociodemographic factors. All data were analyzed using SAS version 9.2 (SAS Institute, Cary, NC, USA).

RESULTS

Descriptive characteristics

As shown in Table 1, the gender and race characteristics of children were similar between CHAMPS and the EDPAPC study. BMI and BMI *z*-score were slightly higher among the participants in CHAMPS compared to those in EDPAPC. The average number of days and hours that children wore the accelerometers were

Table 1. Characteristics of participants in CHAMPS and EDPAPC, mean $\pm$ s.d. or percent

Characteristics	*CHAMPS*[a]	*EDPAPC*[b]	P-*value*[c]
N	263	155	
Age (years)	4.2 ± 0.6	4.0 ± 0.7	0.002
Gender (%)			*0.65*
Boys	48.7	50.9	
Girls	51.3	49.1	
Race (%)			*0.27*
African American	50.9	54.8	
White	40.0	40.0	
Others	9.1	5.2	
Parent education (%)			
>High school	55.9	78.1	<0.001
BMI (kg m^{-2})	16.3 ± 1.6	15.9 ± 1.7	0.03
BMI *z*-score	0.43 ± 1.1	0.05 ± 1.2	<0.001
Wear time[d]			
Number of days	7.5 ± 1.5	7.5 ± 3.9	0.68
Hours per day	13.1 ± 1.2	7.6 ± 0.5	<0.001

[a]Children's Activity and Movement in Preschool Study. [b]Environmental Determinants of Physical Activity in Preschool Children Study. [c]*P*-values for the difference between CHAMPS and EDPAPC participants. [d]Number of days and hours that children wore accelerometers.

7.5 days and 13.1 h per day in CHAMPS, and 7.5 days and 7.6 h per day in the EDPAPC study, respectively.

Time spent in sedentary behavior

The estimated time spent in sedentary behavior using the three cutpoints are presented in Table 2. Depending upon the cutpoint used, the average time spent in sedentary behavior varied from 32 min h^{-1} to 51 min h^{-1} in CHAMPS, and from 38 min h^{-1} to 54 min h^{-1} in the EDPAPC study. In both CHAMPS and EDPAPC study, boys spent less time in sedentary behavior than girls.

Association between sedentary behavior and BMI *z*-score

The associations between sedentary behavior and BMI *z*-score in CHAMPS are presented in Table 3. Across three different cutpoints used, sedentary behavior was inversely associated with BMI *z*-score among CHAMPS participants after adjusting for age, gender, race, parent education level and preschool (Model 1). However, this association was eliminated after additionally adjusting for levels of MVPA (Model 2). In the EDPAPC study, sedentary behavior was not associated with BMI *z*-score after adjusting for potential confounders (Table 3). We did not find any significant interaction indicating that the association between sedentary behavior and BMI *z*-score did not differ by these sociodemographic factors.

DISCUSSION

The association between sedentary behavior and adiposity in the preschool population has not been studied extensively. In the current study, we investigated the association between objectively measured sedentary behavior and BMI *z*-score in two independent samples of preschool children. We found that accelerometry-derived sedentary behavior was not independently associated with BMI *z*-score after adjusting for important confounders, including MVPA, in two samples of preschool children. These findings are of particular importance because some public health authorities have suggested that reducing sedentary behavior may be an important strategy for prevention of obesity in preschool children.[30,31] Within the limitations of a cross-sectional study, our findings indicate that sedentary behavior may not be an independent risk factor for obesity in preschool children.

Three large cross-sectional studies have examined the association between accelerometry-derived sedentary behavior and measures of adiposity in primary school-age children (aged 9–12 years).[32–34] In all the three studies, no association was observed between sedentary behavior and adiposity, after adjusting for

Table 2. Time spent in accelerometry-derived sedentary behavior and MVPA according to three different cutpoints (mean ± s.d.)

	CHAMPS				*EDPAPC*			
	Total	*Boys*	*Girls*	P-*value*[a]	*Total*	*Boys*	*Girls*	P-*value*[a]
N	263	128	135		155	79	76	
Sedentary behavior (min h^{-1})								
<37.5 counts per 15 s	32.4 ± 3.6	32.1 ± 3.8	32.6 ± 3.5	0.27	38.0 ± 4.5	37.3 ± 4.6	38.7 ± 4.4	0.07
<200 counts per 15 s	45.7 ± 2.9	45.1 ± 3.2	46.2 ± 2.5	0.005	47.1 ± 3.8	46.4 ± 3.8	47.7 ± 3.7	0.03
<373 counts per 15 s	51.3 ± 2.3	50.8 ± 2.5	51.8 ± 1.8	<0.001	54.5 ± 1.6	54.3 ± 1.7	54.8 ± 1.5	0.04
Sedentary behavior (min per day)								
<37.5 counts per 15 s	424.8 ± 62.7	423.9 ± 63.0	425.6 ± 62.7	0.84	286.4 ± 34.7	283.5 ± 35.2	289.4 ± 34.1	0.29
<200 counts per 15 s	598.5 ± 67.2	595.4 ± 67.8	601.5 ± 66.8	0.46	354.9 ± 31.9	352.7 ± 31.9	357.2 ± 31.9	0.38
<373 counts per 15 s	672.7 ± 67.5	670.1 ± 67.4	675.2 ± 67.7	0.54	411.5 ± 24.5	412.5 ± 24.2	410.5 ± 25.0	0.61
MVPA (min h^{-1})								
⩾420 counts per 15 s	7.6 ± 2.1	8.1 ± 2.4	7.1 ± 1.7	<0.001	8.0 ± 2.9	8.6 ± 3.0	7.4 ± 2.9	0.02
MVPA (min per day)								
⩾420 counts per 15 s	99.3 ± 28.9	106.1 ± 31.9	92.5 ± 24.1	<0.001	60.8 ± 23.3	65.5 ± 23.8	55.9 ± 21.9	0.01

[a]*P*-values for the difference between boys and girls.

Table 3. Association between sedentary behavior (min h^{-1}) and BMI *z*-score in preschool children

Study sample	*Sedentary cutpoints (counts per 15 s)*	*Model 1*[a]		*Model 2*[b]	
		Standardized β (95% CI)	P-*value*	*Standardized β (95% CI)*	P-*value*
CHAMPS	<37.5	−0.059 (−0.095, −0.023)	0.002	−0.019 (−0.078, 0.039)	0.53
	<200	−0.087 (−0.132, −0.041)	<.001	−0.076 (−0.235, 0.083)	0.35
	<373	−0.111 (−0.171, −0.051)	<.001	−0.333 (−1.342, 0.676)	0.52
EDPAPC	<37.5	0.083 (−0.119, 0.285)	0.42	−0.041 (−0.275, 0.192)	0.73
	<200	0.089 (−0.148, 0.325)	0.46	−0.247 (−0.581, 0.086)	0.14
	<373	0.209 (−0.783, 0.365)	0.47	−0.417 (−0.991, 0.156)	0.15

[a]Adjusted for age, gender, race, parent education and preschool. [b]Adjusted for age, gender, race, parent education, preschool and MVPA.

time spent in MVPA.[32–34] In addition, the largest cross-sectional analysis to date ($N = 20\,871$) reported that accelerometry-derived sedentary behavior was not associated with waist circumference in children and adolescents.[35] To the best of our knowledge, only one study has examined the association between accelerometry-derived sedentary behavior and BMI *z*-score in preschool children.[12] In that study, no significant correlation was found between sedentary behavior and BMI *z*-score. Collectively, based on those data and our findings, it does not appear that an independent association exists between accelerometer-derived sedentary behavior and adiposity in childhood.[12,32–34]

In contrast, accelerometry-derived sedentary behavior consistently has been associated with adiposity in adults, independent of time spent in MVPA.[36–38] A common biological mechanism used to explain the independent association in adults is that high sedentary behavior contributes to lower energy expenditure, which predisposes to excessive weight gain.[39] It is likely that the same mechanism is operating in children.[40] However, one explanation for an absence of a clear association between sedentary behavior and BMI *z*-score in young children could be the absolute level of sedentary behavior. On average, time spent in sedentary behavior is significantly lower in younger children, compared to older children and adults.[35,41] Although preschool children engage in a significant amount of time in sedentary behavior, the level of sedentary behavior may not be sufficient to reduce energy expenditure to the extent needed for an increase in BMI.

Another possible explanation for the absence of a significant association between sedentary behavior and adiposity may be the unique activity pattern of typical preschoolers. Preschoolers' activity is intermittent and sporadic in nature,[42,43] and it is likely that frequent breaks occur in their sedentary behavior. Interestingly, studies have shown that more frequent breaks in sedentary time associate with lower BMI in adults, independent of the total time spent in sedentary behavior.[38,44] Therefore, we speculate that the lack of an association between sedentary behavior and BMI in our sample of preschool children could be due to the high frequency of breaks in sedentary behavior, independent of total sedentary behavior.

Future studies should consider the following issues to better understand the association between sedentary behavior and adiposity in preschool children. Preschool age is a period of fast physical growth, and the adiposity rebound complicates the association between sedentary behavior and adiposity further.[45–47] Although BMI is a good surrogate measure of adiposity in preschool children,[48] it may not be sensitive enough to assess body fatness of young children. Changes in BMI during preschool age are likely due to both body fat and lean-mass changes.[49] Considering these issues, more precise measures of adiposity in preschool children are needed. Also, prospective studies that follow children throughout the period of adiposity rebound are needed to fully understand the relationship between sedentary behavior and BMI in preschool children.

A secondary aim of this study was to determine whether the association between accelerometry-derived sedentary behavior and BMI *z*-score was affected by applying different accelerometry cutpoints. The cutpoints used to define sedentary behavior in preschool children range from <26 counts per 15 s[50] to <1100 counts per 60 s.[20] We observed that the estimated time spent in sedentary behavior varied according to the cutpoints used. However, regardless of the cutpoint used, sedentary behavior was not independently associated with the BMI *z*-score in our samples of preschool children. The results from this comprehensive approach indicate that our finding of no association between sedentary behavior and BMI *z*-score was not biased due to the selection of certain cutpoints.

This study had several strengths and limitations. Strengths include the use of accelerometry to quantify the amount of time spent in sedentary behavior. Whereas other methods (for example, parent reports and direct observation) measure sedentary behavior in preschool children, accelerometry provides an objective assessment and limits the researcher's burden.[13,18] The present study included two relatively large independent samples of preschool children from diverse social and demographic backgrounds. In addition, the children had good compliance with wearing the accelerometers. Accelerometry has limitations to discriminate between sitting and standing, and to capture upper body movement, which may increase preschoolers' energy expenditure level above that of sedentary. Another limitation is that the participants in this study were volunteers from preschools located in one geographic region, and the nature of the cross-sectional study design precludes establishing the causality of findings.

In conclusion, sedentary behavior was not independently associated with BMI *z*-score in large samples of preschool children. Longitudinal studies that account for the growth patterns of preschool children would advance our understanding of the association between sedentary behavior and adiposity in young children.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

1 Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. *JAMA* 2006; **295**: 1549–1555.
2 Freedman DS, Khan LK, Serdula MK, Ogden CL, Dietz WH. Racial and ethnic differences in secular trends for childhood BMI, weight, and height. *Obesity (Silver Spring)* 2006; **14**: 301–308.
3 Quelly SB, Lieberman LS. Global prevalence of overweight and obesity in preschoolers. *Anthropol Anz* 2011; **68**: 437–456.
4 Nader PR, O'Brien M, Houts R, Bradley R, Belsky J, Crosnoe R *et al.* Identifying risk for obesity in early childhood. *Pediatrics* 2006; **118**: e594–e601.
5 Jackson DM, Djafarian K, Stewart J, Speakman JR. Increased television viewing is associated with elevated body fatness but not with lower total energy expenditure in children. *Am J Clin Nutr* 2009; **89**: 1031–1036.
6 Pratt C, Webber LS, Baggett CD, Ward D, Pate RR, Murray D *et al.* Sedentary activity and body composition of middle school girls: the trial of activity for adolescent girls. *Res Q Exerc Sport* 2008; **79**: 458–467.
7 Dennison BA, Erb TA, Jenkins PL. Television viewing and television in bedroom associated with overweight risk among low-income preschool children. *Pediatrics* 2002; **109**: 1028–1035.
8 Lumeng JC, Rahnama S, Appugliese D, Kaciroti N, Bradley RH. Television exposure and overweight risk in preschoolers. *Arch Pediatr Adolesc Med* 2006; **160**: 417–422.
9 Manios Y, Kourlaba G, Kondaki K, Grammatikaki E, Anastasiadou A, Roma-Giannikou E. Obesity and television watching in preschoolers in Greece: the GENESIS study. *Obesity (Silver Spring)* 2009; **17**: 2047–2053.
10 Proctor MH, Moore LL, Gao D, Cupples LA, Bradlee ML, Hood MY *et al.* Television viewing and change in body fat from preschool to early adolescence: The Framingham Children's Study. *Int J Obes Relat Metab Disord* 2003; **27**: 827–833.
11 Sugimori H, Yoshida K, Izuno T, Miyakawa M, Suka M, Sekine M *et al.* Analysis of factors that influence body mass index from ages 3 to 6 years: a study based on the Toyama cohort study. *Pediatr Int* 2004; **46**: 302–310.
12 Cliff DP, Okely AD, Smith LM, McKeen K. Relationships between fundamental movement skills and objectively measured physical activity in preschool children. *Pediatr Exerc Sci* 2009; **21**: 436–449.
13 Cardon GM, De Bl. Are preschool children active enough? Objectively measured physical activity levels. *Res Q Exerc Sport* 2008; **79**: 326–332.

14 Janz KF, Burns TL, Levy SM. Tracking of activity and sedentary behaviors in childhood: the Iowa Bone Development Study. *Am J Prev Med* 2005; **29**: 171–178.
15 Kelly LA, Reilly JJ, Fisher A, Montgomery C, Williamson A, McColl JH *et al.* Effect of socioeconomic status on objectively measured physical activity. *Arch Dis Child* 2006; **91**: 35–38.
16 Reilly JJ, Jackson DM, Montgomery C, Kelly LA, Slater C, Grant S *et al.* Total energy expenditure and physical activity in young Scottish children: mixed longitudinal study. *Lancet* 2004; **363**: 211–212.
17 Williams HG, Pfeiffer KA, O'Neill JR, Dowda M, McIver KL, Brown WH *et al.* Motor skill performance and physical activity in preschool children 2. *Obesity (Silver Spring)* 2008; **16**: 1421–1426.
18 Pate RR, Almeida MJ, McIver KL, Pfeiffer KA, Dowda M. Validation and calibration of an accelerometer in preschool children. *Obesity (Silver Spring)* 2006; **14**: 2000–2006.
19 van Cauwenberghe E, Labarque V, Trost SG, de Bourdeaudhuij I, Cardon G. Calibration and comparison of accelerometer cut points in preschool children. *Int J Pediatr Obes* 2011; **6**: e582–e589.
20 Reilly JJ, Coyle J, Kelly L, Burke G, Grant S, Paton JY. An objective method for measurement of sedentary behavior in 3- to 4-year olds. *Obes Res* 2003; **11**: 1155–1158.
21 Reilly JJ, Penpraze V, Hislop J, Davies G, Grant S, Paton JY. Objective measurement of physical activity and sedentary behaviour: review with new data. *Arch Dis Child* 2008; **93**: 614–619.
22 Byun W, Dowda M, Pate RR. Correlates of objectively measured sedentary behavior in US preschool children. *Pediatrics* 2011; **128**: 937–945.
23 Pate RR, Pfeiffer KA, Trost SG, Ziegler P, Dowda M. Physical activity among children attending preschools. *Pediatrics* 2004; **114**: 1258–1263.
24 Byun W. *How Many Days of Accelerometer Monitoring Predict Sedentary Behavior in Preschoolers? [PhD dissertation]*. ProQuest/UMI: University of South Carolina, 2012.
25 U.S. Census Bureau. State and County Quick Facts 2012.
26 Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z *et al.* 2000 CDC growth charts for the United States: methods and development. *Vital Health Stat 11* 2002; **246**: 1–190.
27 Janz KF, Levy SM, Burns TL, Torner JC, Willing MC, Warren JJ. Fatness, physical activity, and television viewing in children during the adiposity rebound period: The Iowa Bone Development Study. *Prev Med* 2002; **35**: 563–571.
28 Trost SG, Sallis JF, Pate RR, Freedson PS, Taylor WC, Dowda M. Evaluating a model of parental influence on youth physical activity. *Am J Prev Med* 2003; **25**: 277–282.
29 Vale SM, Santos RM, da Cruz Soares-Miranda LM, Moreira CM, Ruiz JR, Mota JA. Objectively measured physical activity and body mass index in preschool children. *Int J Pediatr* 2010; **2010**: 1–6. pii: 479439 doi:10.1155/2010/479439.
30 Department of Health. UK physical activity guidelines 2011.
31 Institute of Medicine. Early Childhood Obesity Prevention: Policies Goals, Recommendations, and Potential Actions 2011.
32 Ekelund U, Sardinha LB, Anderssen SA, Harro M, Franks PW, Brage S *et al.* Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study). *Am J Clin Nutr* 2004; **80**: 584–590.
33 Mitchell JA, Mattocks C, Ness AR, Leary SD, Pate RR, Dowda M *et al.* Sedentary behavior and obesity in a large cohort of children. *Obesity (Silver Spring)* 2009; **17**: 1596–1602.
34 Steele RM, van Sluijs EM, Cassidy A, Griffin SJ, Ekelund U. Targeting sedentary time or moderate- and vigorous-intensity activity: independent relations with adiposity in a population-based sample of 10-y-old British children. *Am J Clin Nutr* 2009; **90**: 1185–1192.
35 Ekelund U, Luan J, Sherar LB, Esliger DW, Griew P, Cooper A. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. *JAMA* 2012; **307**: 704–712.
36 Bankoski A, Harris TB, McClain JJ, Brychta RJ, Caserotti P, Chen KY *et al.* Sedentary activity associated with metabolic syndrome independent of physical activity. *Diabetes Care* 2011; **34**: 497–503.
37 Healy GN, Wijndaele K, Dunstan DW, Shaw JE, Salmon J, Zimmet PZ *et al.* Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab) 5. *Diabetes Care* 2008; **31**: 369–371.
38 Healy GN, Matthews CE, Dunstan DW, Winkler EA, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. *Eur Heart J* 2011; **32**: 590–597.
39 Levine JA, Lanningham-Foster LM, McCrady SK, Krizan AC, Olson LR, Kane PH *et al.* Interindividual variation in posture allocation: possible role in human obesity. *Science* 2005; **307**: 584–586.
40 Martinez-Gonzalez MA, Martinez JA, Hu FB, Gibney MJ, Kearney J. Physical inactivity, sedentary lifestyle and obesity in the European Union. *Int J Obes Relat Metab Disord* 1999; **23**: 1192–1201.
41 Matthews CE, Chen KY, Freedson PS, Buchowski MS, Beech BM, Pate RR *et al.* Amount of time spent in sedentary behaviors in the United States, 2003-2004. *Am J Epidemiol* 2008; **167**: 875–881.
42 Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ, Cooper DM. The level and tempo of children's physical activities: an observational study. *Med Sci Sports Exerc* 1995; **27**: 1033–1041.
43 Brown WH, Pfeiffer KA, McLver KL, Dowda M, Almeida MJ, Pate RR. Assessing preschool children's physical activity: the Observational System for Recording Physical Activity in children-preschool version. *Res Q Exerc Sport* 2006; **77**: 167–176.
44 Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ *et al.* Breaks in sedentary time: beneficial associations with metabolic risk 7. *Diabetes Care* 2008; **31**: 661–666.
45 Cole TJ. Children grow and horses race: is the adiposity rebound a critical period for later obesity? *BMC Pediatr* 2004; **4**: 6.
46 Mei Z, Grummer-Strawn LM, Thompson D, Dietz WH. Shifts in percentiles of growth during early childhood: analysis of longitudinal data from the California Child Health and Development Study. *Pediatrics* 2004; **113**: e617–e627.
47 Rolland-Cachera MF, Deheeger M, Bellisle F, Sempe M, Guilloud-Bataille M, Patois E. Adiposity rebound in children: a simple indicator for predicting obesity. *Am J Clin Nutr* 1984; **39**: 129–135.
48 Goulding A, Gold E, Cannan R, Taylor RW, Williams S, Lewis-Barned NJ. DEXA supports the use of BMI as a measure of fatness in young girls. *Int J Obes Relat Metab Disord* 1996; **20**: 1014–1021.
49 Campbell MW, Williams J, Carlin JB, Wake M. Is the adiposity rebound a rebound in adiposity? *Int J Pediatr Obes* 2011; **6**: e207–e215.
50 Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci* 2008; **26**: 1557–1565.