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# Objectively measured sedentary time, physical activity and markers of body fat in preschool children

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## Abstract

The purpose of this study was to examine the associations between sedentary behavior and moderate to vigorous physical activity (MVPA), measured by accelerometry, with body mass index (BMI) and waist circumference in 357 preschool children. Linear mixed models were used adjusting for race/ethnicity parental education, and preschool. Follow-up analyses were performed using quantile regression. Among boys, MVPA was positively associated with BMI z-score (β = 0.080, $p$ = .04) but not with waist circumference; quantile regression showed that MVPA was positively associated with BMI z-score at the 50$^{th}$ percentile (β = 0.097, $p < .05$). Among girls, no associations were observed between sedentary behavior and MVPA in relation to mean BMI z-score and mean waist circumference. Quantile regression indicated that, among girls at the 90$^{th}$ waist circumference percentile, a positive association was found with sedentary behavior (β = 0.441, $p < .05$), and a negative association was observed with MVPA (β = −0.599, $p < .05$); no associations were found with BMI z-score. In conclusion, MVPA was positively associated with BMI z-score among boys, and MVPA was negatively associated and sedentary behavior was positively associated with waist circumference among girls at the 90$^{th}$ percentile.

### Keywords

Adiposity; BMI; moderate to vigorous physical activity; preschool children; sedentary behavior; waist circumference

## INTRODUCTION

The prevalence of overweight and obesity among children and adolescents has increased in past decades (9;22). Currently, 26.7% of 2- to 5-year-old children in the United States are overweight or obese (23). Clinically, there is evidence that obesity is an independent risk factor for cardiovascular, metabolic, pulmonary and gastrointestinal diseases (5;12;15;17). Therefore, identification of early childhood factors related to overweight and obesity is a public health priority.

Low levels of physical activity and high exposure to sedentary behavior have been associated with overweight and obesity, assessed as total and/or central body fat (28;34). Recent reviews have reported that low sedentary time and high physical activity play a role

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in preventing obesity later in life (14;31). However, the results of these studies were focused on older children and adolescents; few high quality studies have been conducted with preschool children. The lack of quality studies of preschool children was identified as a research gap by one of the recent reviews (14).

The scientific literature includes few studies that have used accelerometry to investigate the association between physical activity and sedentary behavior in relation to markers of body fat among preschool-aged children (7;13;18;20;39–41). The findings reported seem to be contradictory. Therefore, definitive evidence on the relationship between these variables in preschool children is not yet available. The purpose of this study was to examine the associations between objectively measured sedentary behavior and moderate to vigorous physical activity (MVPA) with body mass index (BMI) and waist circumference in preschool children.

# METHODS

## Study design

The preschool children under investigation were participants in the Study of Health and Activity in Preschool Environments (SHAPES). In brief, this was a 3-year intervention study conducted in Columbia, South Carolina, to increase physical activity and decrease sedentary behavior in preschool children. The current study used a cross-sectional design. Baseline data from all preschools in the first year were used (n=186); as well as the data from the control preschools in the second (n=84) and third years (n=87).

## Participants

Children aged 3 to 5 years from 16 public and private preschools took part in this study. Participants were volunteers and thus were not necessarily a representative sample. A total of 357 children provided valid data for physical activity, BMI, and waist circumference, and were included in the analyses. Data collection took place between September 2008 and August 2011. Written informed consent was obtained from each child’s parent or guardian prior to data collection. The study was approved by the University of South Carolina Institutional Review Board.

## Objectively measured physical activity

Physical activity was measured using ActiGraph accelerometers (ActiGraph models GT1M and GT3X; Pensacola, FL 32502, USA). The ActiGraph is a uniaxial accelerometer that measures acceleration in the vertical plane; it is small (2.0 × 1.6 × 0.60 inches), light (27 g) and unobtrusive. For the present study, the monitors were initialized to save data in 15-second intervals (epochs). The short intervals are thought to be better at detecting the spontaneous physical activity of preschool children (25).

Participants were instructed to wear the accelerometers on an elastic belt on the right hip (anterior on the iliac crest) for a total of 5 consecutive weekdays (all accelerometers were removed prior to the weekend). Parents were instructed to remove the accelerometer during water activities (bathing, swimming) and when asleep. Accelerometers had to be worn for a minimum of 2 weekdays and for least 6 hours each day to be included in the present analysis.

Cut-points developed specifically for preschool children were used to determine the time per hour spent in moderate to vigorous physical activity (MVPA, ≥ 420 counts/15-sec) and sedentary behavior (≤ 200 counts/15-sec). Two-hundred counts/15-sec was chosen as the cut-point to differentiate between sedentary and light physical activity. This cut-point was selected because 200 corresponded to the lowest data point for slow walking (2 mph) in an accelerometer calibration study conducted by the investigators (24).

The minutes per hour spent in MVPA and sedentary behavior were calculated for each participant. Days in which total wear time was ≥ 18 hours or < 6 hours were deleted from the analysis.

### Anthropometric measures

Height was measured in duplicate to the nearest 0.1 cm using a portable stadiometer (Shorr Productions; Olney, MD). Weight was measured in duplicate to the nearest 0.1 kg using an electronic scale (Seca, Model 770; Hamburg, Germany). BMI was calculated from the average measures of height and weight (Kg/m$^2$). Overweight/obesity was defined using the age- and sex-specific 85$^{th}$ percentile for BMI from CDC Growth Charts. BMI z-score was created by assessing the deviation of each participant's value from the age-and-sex-specific mean values reported in the CDC growth charts (http://www.cdc.gov/growthcharts/). These percentile-based reference values from the CDC growth charts for overweight status have been used in other studies of preschool children (19;29;40).

Waist circumference was measured to the nearest 0.1 cm using a tension-regulated tape with the participant in the standing position. Measurements were taken midway between the inferior edge of the lowest rib and the superior border of iliac crest, at the end of a gentle expiration. Waist circumference was measured three times, and the average of the three measures was used in the current study. The age- and sex- specific 75th percentiles for waist circumference from the Third National Health and Nutrition Examination Survey (NHANES III) (6) were used to categorize children as having a high or low waist circumference. These percentile-based reference values for central obesity have been used in other studies of preschool children (3;10;42).

### Parent survey

One parent or guardian for each child completed a survey to assess demographic and parental characteristics. Adults reported their child's age and race (categorized as African American, White, Other) and their own education level (categorized as below or above 2 years of college education). Previous studies have considered these variables as factors related to physical activity in preschool children (29;33).

### Statistical analysis

Descriptive statistics for the children were calculated by sex. Sex differences were assessed by t-tests for the continuous variables, and Chi-square tests for nominal data. Linear mixed regression models (SAS 9.2, PROC MIXED) were used to determine the association between sedentary behavior and MVPA with BMI z-score and waist circumference. Separate models were run: one with sedentary behavior, and one with MVPA as the independent variable. The linear mixed regression models were conducted separately by sex because physical activity levels varied between boys and girls. The models included the covariates race/ethnicity and parental education, and the models accounted for children being nested within preschools.

In addition to the linear mixed regression models, we also analyzed our data using quantile regression (SAS 9.2, PROC QUANTREG) (16). This statistical method allowed us to investigate the tails of the BMI z-score and waist circumference distributions, and not just the mean (1;2;38). We present the associations between sedentary behavior/MVPA and BMI z-score/waist circumference at the $10^{th}$, $25^{th}$, $50^{th}$, $75^{th}$ and $90^{th}$ BMI z-score/waist circumference percentiles, separately for boys (n=183) and girls (n=174). The models were adjusted for race/ethnicity and parental education, and models were run separately for sedentary behavior and MVPA. This approach was included in the current study because there is evidence that the association between obesity risk factors in young children do not associate with BMI uniformly across the BMI distribution (1;2). In the context of obesity, the association between physical activity and sedentary behavior at the upper tails of the BMI and waist circumference distributions are of most interest.

## RESULTS

The characteristics of the study sample are shown in Table 1. The prevalence of overweight/obesity was 27.9% in boys and 28.7% in girls, while the prevalence of high-risk waist circumference was 32.8% and 28.7% in boys and girls, respectively. Girls spent 1.0 more minute per hour in sedentary behavior than boys ($p < .01$). Boys engaged in more MVPA (0.9 minute per hour) compared to girls ($p < .001$).

The associations between sedentary behavior and MVPA in relation to mean BMI z-score are shown in Table 2. Among boys, MVPA was positively associated with mean BMI z-score. Specifically, each additional minute per hour spent in MVPA increased the BMI z-score by 0.080 among boys ($p = .04$). Among girls, no significant associations were found. Using quantile regression to investigate the association between MVPA and BMI z-score percentiles (Table 3), MVPA was positively associated with BMI z-score at the $50^{th}$ BMI z-score percentile ($p < .05$). Among girls, no associations were observed between MVPA and BMI z-score percentiles. Sedentary behavior was not associated with BMI z-score percentiles for boys or girls.

The associations between sedentary behavior and MVPA in relation to mean waist circumference are shown in Table 2. No associations were observed between sedentary behavior and waist circumference, or between MVPA and waist circumference, for boys or girls. Using quantile regression (Table 3), no associations were observed among boys between sedentary behavior and/or MVPA and the $10^{th}$, $25^{th}$, $50^{th}$, $75^{th}$ or $90^{th}$ waist circumference percentiles. However, among the girls at the $90^{th}$ waist circumference percentile, a positive association was found with sedentary behavior ($p < .05$), and a negative association was observed with MVPA ($p < .05$).

## DISCUSSION

Our data indicate that among boys, MVPA was positively associated with mean BMI z-score. Previous studies have typically found no associations between sedentary behavior and physical activity (assessed with accelerometry) in relation to measures of adiposity (4;7;18;39). However, two studies have reported positive associations between physical activity and BMI in preschool children (11;20). These observations are interesting given that an association in the opposite direction would have been expected, and negative associations have been published previously (13;21;40;41). However, this positive association may be explained by greater fat free mass among the more active boys (36).

Importantly, quantile regression analyses were included in the current study to investigate the tails of the BMI z-score and waist circumference distributions, and not just the mean (1;2). We determined that MVPA was positively associated with BMI z-score among boys at the 50$^{th}$ BMI z-score percentile. In addition, we observed among girls, a negative association between MVPA and the 90$^{th}$ waist circumference percentile, and a positive association between sedentary behavior and the 90$^{th}$ waist circumference percentile. To the best of our knowledge, no studies have previously used quantile regression to study the association between objective measures of sedentary behavior and MVPA in relation to measures of obesity in preschool children. However, Beyerlein et al. have reported the association between television viewing and BMI using quantile regression in children aged 5 to 6 years (2). In that study, television viewing was positively associated with BMI at the 50$^{th}$ percentile and above with the association strengthening toward the upper tail of the BMI distribution (2). In the current study we did not observe progressively stronger associations between MVPA/sedentary behavior from the lower to the upper tails of the BMI or waist circumference distributions. However, we did observe a negative association between MVPA and the 90$^{th}$ waist circumference percentile in girls, which indicates that more MVPA accumulated by girls could shift the upper tail of the waist circumference distribution to the left. Also in girls, we observed a positive association between sedentary behavior and the 90$^{th}$ waist circumference percentile. Further studies using quantile regression are needed to determine if the upper or lower tails of BMI z-score and waist circumference distributions are influenced equally with exposure to sedentary behavior and MVPA in preschool children.

Due to the cross-sectional design of our study, we were not able to account for the potential influence of the adiposity rebound on our results. Adiposity rebound is the period when adipose tissue increases after the nadir between 3 and 6 years (30;32). An early adiposity rebound has been associated with an increased risk of obesity in later life (13;20;30;32). A study by Moore et al. (20) followed 103 children over 8 years to determine the effect of physical activity on BMI changes from preschool to early adolescence. At baseline, the most active children had higher BMIs, but had the smallest gains in BMI during each subsequent year. Further, the most active children reached the lowest point in their BMI growth curve at about 6 years of age, while the less active children showed consistent increases in BMI after age 5. This indicates that the most active children had later adiposity rebounds and lower BMIs in early adolescence compared to the less active children (20). Therefore, the positive association found between MVPA and BMI z-score among boys in the present study needs careful interpretation. Higher levels of MVPA during the preschool years may lead to lower BMIs in later childhood (20). It therefore remains important to establish an active lifestyle beginning early in childhood (20).

There are limitations of the present study. It is not possible to infer a causal relationship between physical activity, sedentary behavior and body fatness due to the cross-sectional design of the current study. Although we controlled for several potential confounders, residual confounding may remain. It should also be recognized that accelerometers are unable to detect non-weight bearing activities such as swimming or cycling and this is a limitation (27). Nonetheless, accelerometers are considered the method of choice for objectively measuring physical activity in free-living young children (26). We used anthropometric measures to assess body fatness in the current study, and these measures have been shown to provide an accurate marker of total and abdominal fat when compared with dual energy x-ray absorptiometry measurements in preschool children (8;35;37). It is also important to take into account that publication bias may have influenced the evidence in the literature, resulting in fewer studies reporting null associations between sedentary behavior, physical activity and adiposity being published (14).

In conclusion, our cross-sectional study suggests that among boys, MVPA was positively associated with BMI z-scores, and conversely, among girls at the 90$^{th}$ percentile, MVPA was negatively associated and sedentary behavior was positively associated with waist circumference. These findings indicate that associations between physical activity and body composition are complex in young children. Future studies should examine these associations with prospective longitudinal designs and careful assessment of developmental stages.

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**Table 1**

Characteristics of the study sample

| | Boys (n=183) | Girls (n=174) |
|---|---|---|
| | **Mean (SD) or %** | **Mean (SD) or %** |
| Child's race/ethnicity (%) | | |
| African American | 44.8 | 47.7 |
| White | 37.7 | 36.8 |
| Other | 17.5 | 15.5 |
| Parental education level (%) | | |
| ≥ 2 y degree | 60.1 | 15.5 |
| Age (y) | 4.5 ± 0.4 | 4.6 ± 0.3 |
| Weight (kg) | 19.0 ± 3.4 | 18.9 ± 3.1 |
| Height (cm) | 107.3 ± 5.2 | 107.5 ± 4.8 |
| Body Mass Index (Kg/m$^2$) | 16.3 ± 1.8 | 16.3 ± 1.8 |
| BMI z-score | 0.5 ± 1.2 | 0.5 ± 0.9 |
| Overweight/obese (%) | 27.9 | 28.7 [a] |
| Waist circumference | 52.6 ± 4.7 | 53.9 ± 4.8 |
| High-risk waist circumference (%) | 32.8 | 28.7 |
| Sedentary behavior (min/h) | 44.1 ± 3.1 | 45.2 ± 3.3 [b] |
| MVPA (min/h) | 8.2 ± 2.2 | 7.3 ± 2.0 [c] |

[a] Difference between boys and girls, $P < .05$

[b] Difference between boys and girls, $P < .01$

[c] Difference between boys and girls, $P < .001$

Note: BMI: body mass index; MVPA: moderate to vigorous physical activity.

**Table 2**

Mixed model coefficients (β), examining the association of sedentary behavior and MVPA with BMI z-score and waist circumference by sex [a].

| Dependent Variable | Predictors | Boys (n=183) β (SE) | Boys (n=183) P | Girls (n=174) β (SE) | Girls (n=174) P |
|---|---|---|---|---|---|
| BMI z-score [b] | Sedentary (min/h) | −0.050 (0.028) | .07 | 0.014 (0.023) | .51 |
| | MVPA (min/h) | 0.080 (0.039) | .04 | −0.024 (0.036) | .51 |
| Waist Circumference [b] | Sedentary (min/h) | −0.152 (0.113) | .18 | 0.154 (0.117) | .19 |
| | MVPA (min/h) | 0.233 (0.160) | .15 | −0.190 (0.187) | .31 |

[a] Covariates for the sex-specific models were race/ethnicity, parental education and preschool.

[b] Two separate models: one with sedentary behavior and one with MVPA as the independent variable.

Note: BMI: body mass index; MVPA: Moderate to vigorous physical activity; SE: Standard error.

## Table 3

Adjusted[a] regression coefficients (standard error) for sedentary behavior[b] and MVPA[b] with BMI z-score percentiles and waist circumference percentiles by sex.

| | **BMI z-score: Boys (n=183)** | | | | |
|---|---|---|---|---|---|
| | **10th Percentile** | **25th Percentile** | **50th Percentile** | **75th Percentile** | **90th Percentile** |
| Sedentary (min/h) | −0.017 (0.045) | −0.033 (0.034) | −0.054 (0.034) | −0.072 (0.039) | −0.092 (0.074) |
| MVPA (min/h) | 0.012 (0.089) | 0.053 (0.053) | 0.097 (0.048) [c] | 0.101 (0.055) | 0.134 (0.115) |
| | Waist circumference (cm): Boys (n=183) | | | | |
| Sedentary (min/h) | −0.022 (0.156) | −0.195 (0.108) | −0.039 (0.143) | −0.094 (0.158) | −0.247 (0.314) |
| MVPA (min/h) | 0.040 (0.239) | 0.288 (0.153) | 0.083 (0.175) | 0.380 (0.223) | 0.527 (0.491) |
| | BMI z-score: Girls (n=174) | | | | |
| Sedentary (min/h) | 0.007 (0.036) | −0.010 (0.035) | −0.003 (.024) | 0.024 (0.03) | 0.038 (0.039) |
| MVPA (min/h) | −0.010 (0.054) | 0.003 (0.053) | −0.008 (0.039) | −0.036 (0.047) | −0.105 (0.070) |
| | Waist circumference (cm): Girls (n=174) | | | | |
| Sedentary (min/h) | −0.060 (0.146) | −0.079 (0.147) | 0.071(0.102) | 0.005 (0.128) | 0.441 (0.191) [c] |
| MVPA (min/h) | −0.096 (0.228) | 0.118 (0.227) | −0.092 (0.130) | −0.160 (0.221) | −0.599 (0.302) [c] |

[a] Analyses were adjusted for race/ethnicity and parental education.

[b] Separate models: one with sedentary behavior and one with MVPA as the independent variable.

[c] $P < .05$

Note: BMI: body mass index; MVPA: Moderate to vigorous physical activity.