Associations Between Sedentary Behavior and Blood Pressure in Young Children

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Objective: To examine the effect of sedentary behavior on blood pressure (BP) in young children using different indicators of sedentariness.

Design: Cross-sectional study.

Setting: A rural Midwestern US community.

Participants: Children aged 3 to 8 years (N=111).

Intervention: Adiposity was assessed using dual energy x-ray absorptiometry. Objective measurements of sedentary activity were obtained from the accelerometers that participants wore continuously for 7 days. Measurements of television (TV) viewing, computer, and screen time (TV + computer) were obtained via parent report.

Main Outcome Measures: Systolic and diastolic BP.

Results: The sample spent a mean of 5 hours per day in sedentary activities, of which 1.5 hours were screen time. Accelerometer-determined sedentary activity was not significantly related to systolic BP or diastolic BP after controlling for age, sex, height, and percentage of body fat. However, TV viewing and screen time, but not computer use, were positively associated with both systolic BP and diastolic BP after adjusting for potential confounders. Participants in the lowest tertile of TV and screen time had significantly lower levels of systolic and diastolic BP than participants in the upper tertile.

Conclusions: Sedentary behaviors, particularly TV viewing and screen time, were associated with BP in children, independent of body composition. Other factors that occur during excessive screen time (eg, food consumption) should also be considered in the context of sedentary behavior and BP development in children.


The recent secular trend in obesity is a major public health concern. The clustering of cardiovascular disease risk factors in overweight youth suggests that risks may be immediate and not just indicative of potential future problems. The effect of obesity on elevated blood pressure (BP) is a specific concern because there is evidence in favor of tracking BP from childhood into adulthood. Although genetic factors are associated with BP, a healthy lifestyle—specifically, diet and physical activity—and sleep seems to be a relevant contributor to BP levels in children. However, associations between sedentary behavior and BP have not been clearly established in youth, and no studies have examined associations in younger children (≤9 years).

In most studies, sedentary behavior is typically identified as time spent watching television (TV) because it is the most popular form of media use. Nevertheless, recommendations for sedentary activity use the terms of overall media use or screen time. However, results from recent studies indicate that computer use and video
game play may have different metabolic and physiologic effects.27 Hence, time spent in TV viewing, computer use, and screen time should be considered independently in health-related research. Sedentary behavior is most typically assessed with proxy reports by parents,28 but objective data can also be obtained using accelerometers.29 The time spent in specific sedentary behaviors cannot be determined, but it is possible to measure low-energy expenditure levels.30

To our knowledge, no studies have examined the associations between sedentary behavior and BP in young children using different indicators of sedentariness (ie, TV watching, computer use, screen time, and objectively assessed time in sedentary activity). Currently, it is unknown whether sedentary behavior is associated with higher levels of BP in children during the adiposity rebound period. For effective prevention of hypertension and cardiovascular disease, it is important to better understand the influence of sedentary behaviors on BP. Therefore, the purpose of this study was to examine the associations between sedentary behavior and BP in young children.

METHODS

PARTICIPANTS

Participants for the current analysis included 57 boys and 54 girls (N=111) aged 3 through 8 years from a rural US community in the Midwest (population, 30 000) who completed correctly assessments of anthropometry, body composition, BP, and sedentary behavior by accelerometer and parent report. Children were recruited from local preschools and elementary schools through verbal and written advertisements and by word of mouth. Parental consent and child assent were obtained for all participants after the study procedures were explained. The protocol for the present study was approved by the institutional review board of the University of Nebraska at Kearney.

ANTHROPOMETRY

Anthropometric measurements were assessed for each child using standard procedures. Participants wore light clothing and removed their shoes before stature and body weight were assessed. Stature was measured to the nearest 0.1 cm using a wall stadiometer, and body weight was measured to the nearest 0.01 kg using a standard balance beam scale. Body mass index was calculated as weight in kilograms divided by height in meters squared.

BODY COMPOSITION

Fat mass was assessed using dual energy x-ray absorptiometry with a densitometer (DPX-L; Lunar Radiation Corporation, Madison, Wisconsin). Whole-body scans were performed on participants while they were wearing light clothing and lying supine. The Lunar DPX-L densitometer has been well validated31 and has been used as the criterion measure for a number of comparisons with field-based methods (eg, body mass index, bioelectrical impedance, and anthropometry) in young children.32 To ensure reliability, a phantom calibration was performed before use. Adiposity measurements were determined using the pediatric medium scan model in the software for the densitometer (DPX-L, software version 1.5d; Lunar Radiation Corporation). Body fat variables derived from dual energy x-ray absorptiometry included percentage of body fat as well as fat mass and trunk fat mass (in kilograms). The upper trunk was separated from the arms by a line from the axilla to the acromion. The lower trunk was separated from the legs by an oblique line through the femoral neck.

RESTING BP

Resting BP was measured in accordance with standard procedures and recommendations, as described elsewhere.33 A clinical mercury sphygmomanometer was used in conjunction with a stethoscope placed over the brachial artery below the bottom edge of the cuff. Appropriate cuff size was determined by measuring the circumference of the right upper arm at its largest point. Systolic BP (as determined by the first Korotkoff sound) and diastolic BP (as determined by the fifth Korotkoff sound) were measured after participants had been seated for 10 minutes and with their right arms supported and both feet on the floor. Three measurements were taken at 1-minute intervals, and the mean was used for data analysis.

SEDENTARY BEHAVIOR

Objective Assessment

Objective sedentary activity was assessed using an accelerometer (ActiGraph, model 7164; Manufacturing Technology, Inc, Fort Walton, Florida). The ActiGraph is a small (5.1×3.8×1.5 cm), lightweight (45 g), and uniaxial accelerometer designed to detect vertical acceleration ranging in magnitude from 0.05g to 2.00g with a frequency response of 0.25 to 2.50 Hz. This monitor has been validated in both field and free-living research34 and has been used to assess activity patterns in numerous studies.35-38 Instructions were given to both the parent and child regarding proper placement and wearing procedures for the activity monitor. Specifically, the accelerometers were worn over the right hip, anterior to the iliac crest, and participants were asked to wear the monitor at all times with the exception of sleeping and water activities, such as bathing and swimming. Participants wore the monitor for 7 consecutive days, after which the monitors were returned and uploaded using software provided by the manufacturer. For the current study, 30-second epochs were used in concordance with the recommendations for this age group.

Data were exported into a spreadsheet (Excel; Microsoft Corporation, Redmond, Washington) and then imported into SAS statistical software, version 9.1 (SAS Institute, Inc, Cary, North Carolina) for processing. Detailed screening procedures were used to ensure that the accelerometers were worn as directed and that the monitors were functioning properly. Specifically, adherence checks were performed by assessing consecutive missing data during the hours of typical wear time (9 AM to 7 PM). A day of monitoring was considered nonadherent if it contained 3 or more 20-minute periods of missing data (0 counts). Children with complete data for at least 2 weekdays and 1 weekend day were included in the current study. A cutoff point of less than 50 counts per 30 seconds was used in this study to estimate time (in minutes) spent in sedentary activity.38 This threshold has been shown to capture sedentary activities such as watching TV, playing video games, painting, sitting, and other activities with low levels of physical activity.39 40

Parental Report

The average time spent each day (weekdays and weekend days combined) in screen time (TV, video, computer, and video game
There were no significant differences in age, height, weight, and body mass index, and systolic or diastolic BP between girls and boys. Body fat measurements were significantly higher among girls than boys. Parental reported screen time approximated 1.5 hours per day and objectively measured sedentary time 5 hours per day. Boys spent significantly more time using computers than did girls (P = .004). Other sedentary activity measurements did not show significant differences between girls and boys. The range of values for sedentary behaviors should be noted.

Partial correlations, controlling for sex, age, and height, showed positive associations between body fat measurements and BP. Systolic BP was significantly associated with percentage of body fat (r = 0.344; P < .001), total fat mass (r = 0.245; P = .01), and trunk fat (r = 0.285; P = .003). Diastolic BP was also significantly associated with percentage of body fat (r = 0.237; P = .01) and trunk fat (r = 0.217; P = .02).

The results of the regression analysis are presented in Table 2. Accelerometer-determined sedentary activity was not significantly associated with BP. Time spent in TV viewing was positively associated with both systolic BP (P = .001) and diastolic BP (P = .02), whereas time spent using the computer was not significantly associated with BP values (P = .18 and P = .23, respectively). Screen time was positively associated with systolic BP (P = .002) but not with diastolic BP (P = .15). Age, sex, height, and percentage of body fat explained 29% of the variation in systolic BP (adjusted R² = 0.29) and 24% in diastolic BP (adjusted R² = 0.24). Additional analyses using total fat mass and trunk fat measurements as confounders instead of percentage of body fat showed similar results (data not shown).

Systolic BP (F = 0.07; P = .94) and diastolic BP (F = 1.78; P = .17) were not significantly different when stratified by tertiles of objectively measured sedentary activity (Figure 1). There were significant trends in time spent in TV viewing, stratified by tertiles for both systolic BP and diastolic BP.
(F, 8.82; P < .001) and diastolic BP (F, 3.39; P = .04). Significant contrasts in systolic and diastolic BP were found between the lowest tertile and the highest tertile of time spent watching TV (Figure 2). Values for BP across tertiles of time spent using computers were borderline significant for systolic BP (F, 3.09; P = .05) and not significant for diastolic BP (F, 1.20; P = .30) (Figure 2). Systolic BP (F, 6.10; P = .003) but not diastolic BP (F, 0.32; P = .72) was also significantly different across tertiles of screen time. Analysis of covariance adjusted for confounders also showed a trend between systolic BP values by tertiles of screen time (F, 6.10; P = .003) but not with diastolic values (F, 0.32; P = .72). Upon individual comparison, a significant contrast was found when comparing the lowest tertile to the highest tertile in diastolic BP (Figure 2). Tertile means, 95% confidence intervals, and ranges of sedentary activities measured objectively and via parent report are displayed in Table 3.

**Table 2. Association Between Blood Pressure and Sedentary Behavior**

<table>
<thead>
<tr>
<th>Model</th>
<th>Predictor Variable</th>
<th>β</th>
<th>SEM</th>
<th>R²</th>
<th>P Value</th>
<th>β</th>
<th>SEM</th>
<th>R²</th>
<th>P Value</th>
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</thead>
<tbody>
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<td>0.009</td>
<td>0.07</td>
<td>.47</td>
<td>0.030</td>
<td>0.008</td>
<td>0.03</td>
<td>.73</td>
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<tr>
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<td>Television viewing</td>
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<td>0.365</td>
<td>0.33</td>
<td>.001</td>
<td>0.201</td>
<td>0.346</td>
<td>0.23</td>
<td>.02</td>
</tr>
<tr>
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<td>Computer use</td>
<td>0.117</td>
<td>0.396</td>
<td>0.13</td>
<td>.18</td>
<td>0.108</td>
<td>0.366</td>
<td>0.12</td>
<td>.23</td>
</tr>
<tr>
<td>4</td>
<td>Screen time</td>
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<td>0.372</td>
<td>0.29</td>
<td>.002</td>
<td>0.122</td>
<td>0.355</td>
<td>0.14</td>
<td>.15</td>
</tr>
</tbody>
</table>

aVariables adjusted for sex, age, height, and percentage of body fat.

bValues were transformed (natural log) before analyses.

The results of this study show that sedentary behavior was positively associated with BP in young children. More specifically, TV viewing and screen time (computed by summing the time spent in TV viewing and computer use) were associated with BP after controlling for age, sex, height, and adiposity.

**Figure 1.** Mean systolic (A) and diastolic (B) blood pressure stratified in tertiles (low, middle, and high) by time spent in sedentary activity, assessed with an accelerometer. Errors bars represent standard error of the mean. Data were analyzed by analysis of covariance with Bonferroni adjustment for sex, age, height, and percentage of body fat.

**Figure 2.** Mean systolic (A) and diastolic blood pressure (B) stratified in tertiles (low, middle, and high) by time spent watching television, using a computer, and screen time, assessed by parent report. Errors bars represent standard error of the mean. Data were analyzed by analysis of covariance with Bonferroni adjustment for sex, age, height, and percentage of body fat.

*Significantly different from the low tertile (P = .01). †Significantly different from the low tertile (P = .001). ‡Significantly different from the low tertile (P = .002). §Significantly different from the low tertile (P = .047).

Although previous studies show that sedentary behaviors are related to adiposity, and adiposity is related to BP, this is the first study, to our knowledge, to examine associations between sedentary behaviors and BP in children during the adiposity rebound period. Several similar studies have been conducted in older children with the same purpose. Guillaume et al found positive associations between TV time and systolic BP in...
The prevalence rates for elevated BP among US children have been increasing in recent years. Effective prevention strategies are clearly needed given the tracking of BP and the early development of hypertension, obesity, and other cardiovascular disease risk factors in youth. Several studies indicate that the heritability of BP is estimated to be about 30%. Although genetics clearly affect BP, lifestyle also plays an important role in explaining the remaining variance in resting BP. Diet and physical activity both have been shown to be associated with hypertension, but special attention is given here to the association between TV viewing and BP.

The authors did not find significant associations between time spent watching TV and systolic or diastolic BP. In contrast, Wells et al. found that 1 hour per day of TV viewing was associated with an increase of 0.35 mm Hg in systolic BP and 0.25 mm Hg in diastolic BP among 10- to 12-year-old Brazilian children. However, a limitation of these studies is that they did not control for adiposity. Pardee et al. found that time spent watching TV was associated with risk of hypertension in severely obese children, controlling for individual weight status. However, a longitudinal study also found no association between TV viewing in childhood and BP in adulthood, independent of adiposity.

The American Academy of Pediatrics recommends that parents should limit children's screen time to no more than 2 hours per day. Our results and those of others show that young children spend much of their waking hours in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activities. The youth in our sample spent an average of 5 hours per day in sedentary activi...
behavior is an important and promising strategy to prevent obesity and hypertension in the young. Behavioral choice theories suggest that reducing sedentary behaviors is a way to increase physical activity. A current randomized controlled clinical trial examined the effects of reducing television viewing and computer use on children’s adiposity during the adiposity rebound period. The results suggested that reducing television viewing and computer use may have an important role in preventing obesity among 4- to 7-year-old children.

The strengths of this study include the use of direct measures, such as dual energy x-ray absorptiometry, to evaluate adiposity and to examine sedentary behavior using several indicators. Field methods to evaluate adiposity have significantly underestimated adiposity in younger children. Ideally, these evaluations should be made using direct measures such as dual energy x-ray absorptiometry or underwater weighing. On the other hand, TV viewing is the most common indicator of sedentary behavior, although the recommendation from the American Academy of Pediatrics considers overall media use. Thus, TV viewing and computer use are generally summed to obtain screen time. However, metabolic and physiologic responses, including systolic and diastolic BP values, to video game play among children were different than time spent watching TV, which suggests that TV viewing and computer use should not be combined exclusively as screen time. Likewise, the new-generation computer games may promote slight increases in physical activity compared with traditional sedentary computer games. Another strength of this study was the inclusion of objectively measured time in sedentary behavior by accelerometer. Sedentary behaviors may be defined as “activities that do not increase energy expenditure substantially above the resting level.” Considering this definition, sedentary behavior involves energy expenditure at the level of less than 1.5 metabolic equivalent tasks and includes activities such as sitting or lying down, regardless of whether screen time (TV, video games, etc.) is occurring. Further research is warranted to understand the effect of sedentary behavior on health (eg, obesity, cardiovascular disease, and metabolic syndrome) using this definition.

Our study has 2 limitations that should be considered when interpreting the results. First, time spent in TV viewing and computer use was assessed by parent report. Although parent report is widely used to assess several lifestyle indicators in younger children, differences with objective methods may be large. Recent studies highlight that parents underestimate their child’s TV time by more than 3 hours per week compared with an objective method when the child has a TV in the bedroom and overestimate television time by 4 hours per week when there is not a TV in the child’s bedroom. Unfortunately, we did not determine whether children had TVs in their bedrooms. Second, there is no consensus on the threshold for sedentary activity using the ActiGraph accelerometer. Previous studies have used different cutoff points in children, and differences among published children’s cutoff points have been described elsewhere.

In conclusion, the results of this study showed that TV viewing and screen time were associated with BP independent of body composition in children. Given that total objective sedentary time was not associated with BP, it appears that other factors, which occur during excessive screen time, should also be considered in the context of sedentary behavior and BP development in children.


43. Arnone H. Glasow—Telling a teenager the facts of life is like giving a fish a bath.