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.

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.

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.

The recent secular trend in obesity is a major public health concern.1 The clustering of cardiovascular disease risk factors in overweight youth suggests that risks may be immediate and not just indicative of potential future problems.2 The effect of obesity on elevated blood pressure (BP)3,4 is a specific concern because there is evidence in favor of tracking BP from childhood into adulthood.3 Although genetic factors are associated with BP,6-9 a healthy lifestyle—specifically, diet,10,11 physical activity,12-14 and sleep15—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,15-18 and no studies have examined associations in younger children (<9 years). Although often assumed to be correlated, physical activity and sedentary behavior are increasingly being viewed as independent constructs.19 Hamilton and colleagues20 have posited the notion of “physiologic inactivity,” whereby they differentiated between too much sitting (physiologic inactivity) and structured exercise (physiologic exercise). Daily physical inactivity or low nonexercise activity may be independently associated with tangible disease risks.

There is clear evidence of the association between adiposity and BP in children.21 Given the effects of adiposity on BP during childhood, attention should be paid to the adiposity rebound period between ages 3 and 7 years.22,23 In previous studies, we have found that adiposity is associated with BP in 3- to 8-year-old children24 and that sedentary behaviors were positively associated with adiposity.25 For these reasons, studies hypothesizing associations between sedentary behaviors and BP in this specific period must control for adiposity to examine the independent influence of sedentary behaviors on BP.

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.26 However, results from recent studies indicate that computer use and video
game play may have different metabolic and physiologic effects. 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, but objective data can also be obtained using accelerometers. The time spent in specific sedentary behaviors cannot be determined, but it is possible to measure low-energy expenditure levels.

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 validated 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. 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 hips 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. 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 research and has been used to assess activity patterns in numerous studies. 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. 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.

Parental Report
The average time spent each day (weekdays and weekend days combined) in screen time (TV, video, computer, and video game...
The descriptive characteristics of the total sample and differences between girls and boys are shown in **Table 1**. There were no significant differences in age, height, weight, 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 = 0.34; P < .001), total fat mass (r = 0.245; P < .001), and trunk fat (r = 0.237; P < .01), and 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...
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 ($F_{1,3.09} = 3.09; P = .05$) and not significant for diastolic BP ($F_{1,2.20} = 0.32; P = .58$) (Figure 2). Systolic BP ($F_{1,6.10} = 6.10; P = .003$) but not diastolic BP ($F_{1,0.32} = 0.32; P = .72$) 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 ($F_{1,6.10} = 6.10; P = .003$) but not with diastolic values ($F_{1,0.32} = 0.32; P = .72$).

Upon individual comparison, a significant contrast was found when comparing the lowest tertile to the highest tertile in diastolic BP (Figure 2). Ter
tile means, 95% confidence intervals, and ranges of sedentary activities measured objectively and via parent report are displayed in Table 3.

**COMMENT**

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.

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

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Table 2. Association Between Blood Pressure and Sedentary Behavior

<table>
<thead>
<tr>
<th>Model</th>
<th>Predictor Variable</th>
<th>Coefficient</th>
<th>SEM</th>
<th>$R^2$</th>
<th>$P$ Value</th>
<th>Coefficient</th>
<th>SEM</th>
<th>$R^2$</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sedentary activity</td>
<td>0.064</td>
<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>
</tr>
<tr>
<td>2</td>
<td>Television viewing</td>
<td>0.272</td>
<td>0.365</td>
<td>0.32</td>
<td>.001</td>
<td>0.201</td>
<td>0.346</td>
<td>0.23</td>
<td>.02</td>
</tr>
<tr>
<td>3</td>
<td>Computer use</td>
<td>0.117</td>
<td>0.386</td>
<td>0.13</td>
<td>.13</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>
<td>0.245</td>
<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>

*a* Variables adjusted for sex, age, height, and percentage of body fat.  
*b* Values were transformed (natural log) before analyses.
screen time, as discussed in the Introduction and the pre-
seding paragraphs. Nonetheless, reducing sedentary be-
cause of these studies is that they did not control for
sedentary activity.12-14 Both have been shown to be associated
with lower BP levels.12 Andersen et al13 also found asso-
ciations between accelerometry-determined physical ac-
tivity and BP, lifestyle also plays an important role in explaining
BP. In contrast, Wells et al15 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 al18 found that time spent watch-
ing TV was associated with risk of hypertension in se-
etile Mean (95% CI) Range

Table 3. Sedentary Activity, TV Viewing, Computer Use, and Screen Time by Tertile

<table>
<thead>
<tr>
<th>Tertile</th>
<th>Sedentary activity, min/d</th>
<th>TV viewing, min/d</th>
<th>Computer use, min/d</th>
<th>Screen time, min/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>224.85 (217.02 to 232.69)</td>
<td>8.57 (4.87 to 12.27)</td>
<td>0.86 (3.10 to 8.61)</td>
<td>1.84 (6.79 to 14.88)</td>
</tr>
<tr>
<td>Middle</td>
<td>284.03 (278.30 to 297.77)</td>
<td>63.08 (57.95 to 68.22)</td>
<td>5.86 (3.10 to 8.61)</td>
<td>10.84 (6.79 to 14.88)</td>
</tr>
<tr>
<td>High</td>
<td>390.72 (384.31 to 417.13)</td>
<td>155.16 (137.13 to 173.20)</td>
<td>65.10 (54.75 to 75.45)</td>
<td>194.84 (175.99 to 213.50)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; ellipses, not applicable; TV, television.

The prevalence rates for elevated BP among US children have been increasing in recent years.3,4 Effective pre-
vention strategies are clearly needed given the tracking of BP and the early development of hypertension, obe-
sity, and other cardiovascular disease risk factors in youth.5 Several studies indicate that the heritability of BP is es-
timated to be around 30%.6 Although genetics clearly affect BP, lifestyle also plays an important role in explain-
ing the remaining variance in resting BP. Diet10,11 and phys-
ical activity12-14 both have been shown to be associated with hypertension, but special attention is given here to the
physical activity results. In a study of 5500 children from the United Kingdom aged 11 to 12 years, higher levels of
accelerometry-determined total physical activity and moderate-to-vigorous physical activity were associated with lower BP levels.12 Andersen et al13 also found asso-
ciations between accelerometry-determined physical ac-
tivity and systolic and diastolic BP in children from the
European Youth Heart Study. Similarly, a moderate dose-
response relationship was found between physical activ-
ity and BP in a representative sample of US children par-
ticipating in the 2003-2004 National Health and Nutrition
Examination Surveys.14 Recent findings also indicate that sleep duration is inversely associated with BP in chil-
dren,15 but additional research is needed to confirm these
findings.

Our results indicate that sedentary activity assessed by accelerometer was not associated with BP. However,
screen time and, more particularly, TV viewing was sig-
ificantly associated with BP, independent of adiposity. There are several possible explanations for the associa-
tion between TV viewing and BP. First, isolated physi-
ocal inactivity while watching TV may have direct effects on BP. Second, isolated unhealthy behaviors that children may participate in during TV viewing (eg, eating) may indi-
rectly produce the effects on BP. Time spent watching TV has been associated with behaviors such as in-
creased consumption of high-fat, high-sugar, and salty foods and decreased consumption of fruits and vege-
tables.45-48 Furthermore, these behaviors are com-
monly associated with adiposity in children and conse-
quently with BP. Third, both inactivity and related
unhealthy behaviors during TV time may produce syn-
nergistic effects on BP. Last, TV viewing may disrupt sleep hours in children.49 However, these explanations can-
not be directly elucidated from our results.

Besides the possible interactions of diet, sleep dura-
tion, and TV viewing with BP, our findings also suggest that displacing screen time with even low-intensity physi-
ical activity may be an important preventive factor dur-
ing childhood. Moreover, we observed that participants in the lowest tertile of TV viewing had significantly lower systolic and diastolic BP than participants in the upper tertiles. Participants in the lowest tertile of screen time were also significantly different in systolic BP than par-
ticipants in the upper tertile of screen time. Participants in the low-tertile groups spent an average of less than 30
min/d in TV viewing and screen time. Hence, these re-
results suggest that 30 minute per day of media use may be a reasonable threshold in young children to prevent
higher levels of BP.

The American Academy of Pediatrics recommends that parents should limit children’s screen time to no more
than 2 hours per day.26 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, of which 1.5 hours were screen time. Results from the 1999-2002 National Health and Nutrition Examination Surveys indicated that 31.4%, 6.1%, and 37.3% of 2- to 5-year-old children spent more than 2 hours per day in TV viewing, computer use, and screen time, re-
spectively.39 It is worth remembering that the recom-
mendation proposed by the American Academy of Pe-
diatrics only includes sedentary activities related to media use. In contrast, Corbin and Pangrazi40 recommend limiting extended periods of 2 hours or more of sedentary activities (whether media use or not) for children, espe-
cially during the daytime. This recommendation is in line with the idea of the physical inactivity paradigm.28 How-
ever, our findings are limited to screen time, and BP may be related to diet and sleeping patterns influenced by
screen time, as discussed in the Introduction and the pre-
ceeding paragraphs. Nonetheless, reducing sedentary be-

6- to 12-year-old Belgium boys but not girls. Likewise,
Ekelund et al17 examined the associations between TV
viewing and metabolic risk in the samples of 9- and 15-
year-old children from the European Youth Heart Study.
The authors did not find significant associations be-
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mm Hg in systolic BP and 0.25 mm Hg in diastolic BP
among 10- to 12-year-old Brazilian children. However,
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 underestimate 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, metabolics 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 independently 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.

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Author Contributions: Mr Martinez-Gomez and Drs Welk and Eisenmann had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Heelan and Eisenmann. Acquisition of data: Tucker, Heelan, and Eisenmann. Analysis and interpretation of data: Martinez-Gomez, Tucker, Welk, and Eisenmann. Drafting of the manuscript: Martinez-Gomez, Welk, and Eisenmann. Critical revision of the manuscript for important intellectual content: Martinez-Gomez, Tucker, Heelan, Welk, and Eisenmann. Statistical analysis: Martinez-Gomez and Welk. Obtained funding: Heelan and Eisenmann. Administrative, technical, and material support: Heelan. Supervision: Welk and Eisenmann.

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Additional Information: This research was conducted by Mr Martinez-Gomez while working at Iowa State University as a visiting scholar.

Additional Contributions: Heather McArel, BSc, Ryan Krueger, BSc, Ashley Scantling, BSc, and Bryce Abbey, MSc, assisted with data collection.

REFERENCES


**Telling a teenager the facts of life is like giving a fish a bath.**

—Arnold H. Glasow