Weight Status, Physical Activity, and Vascular Health in 9- to 12-Year-Old Children

Heather M. Hayes, Joey C. Eisenmann, Karin Pfeiffer, and Joseph J. Carlson

Background: The purpose of this study was to determine the independent and joint association of weight status and physical activity on resting blood pressure and C-reactive protein in children. Methods: Participants were 174 (71 males, 103 females) children (mean age = 10.5 ± 0.4 yrs). Physical activity was self-reported, body mass index was calculated from measured height and body mass, and blood pressure was measured according to standard procedures. A subset of 91 children had C-reactive protein measured by fingerstick blood sample. Four weight/physical activity groups were created by cross tabulation of weight status classification and physical activity level. Results: The prevalence of low physical activity (< 5 days/wk moderate-vigorous activity) did not differ between overweight and normal weight children (50%). Physical activity was not correlated with C-reactive protein (r = 0.01; P = 0.91) and C-reactive protein was not significantly different between physical activity groups (P = 0.87). Physical activity did not modify the difference in blood pressure or C-reactive protein within weight categories. Conclusions: Fatness (specifically overweight and obesity), but not physical activity, was shown to be associated with blood pressure and C-reactive protein levels in children. Physical activity did not attenuate blood pressure or C-reactive protein in overweight and obese children.

Keywords: adiposity, childhood, blood pressure, C-reactive protein

Recent estimates indicated that 12% of children and adolescents were at or above the 97th percentile for body mass index (BMI). Given the pediatric obesity epidemic, there is much attention paid to physical activity (PA) and health-related fitness in overweight and obese children. We have previously shown that aerobic fitness attenuates the relationship between adiposity and cardiovascular disease (CVD) risk factors in youth. It is important to note that PA and aerobic fitness are separate constructs and approaches to the prevention of overweight and cardiovascular health focus on PA rather than aerobic fitness.

A prominent risk factor for elevated blood pressure and other markers of atherosclerosis is obesity. Physical activity has been shown to have a low to moderate inverse relationship with blood pressure (BP) in children and adolescents. Mark et al observed an inverse dose-response relationship between both total PA and moderate-to-vigorous PA and BP in 8- to 17-year-olds from the 2003–2004 NHANES. The few studies that have examined the relationship between PA and C-reactive protein (CRP) have shown inconsistent and generally weak correlations. Parrett et al recently examined the joint association of physical activity and fatness in prepubescent children and found an inverse relationship between steps per day and CRP (r = −0.49). No joint association was found with physical activity and fatness; however, the results may have been influenced by multicollinearity in the model and not accounting for sex differences in CRP distribution. Although the independent relationships between PA and BP or CRP have been examined, limited research has evaluated differences in these CVD risk factors in overweight children who meet or do not meet PA recommendations. While research has shown that overweight or obese youth are, on average, less active, when compared with normal weight youth, a few studies have shown overweight or obese children meeting or even exceeding current PA recommendations. Therefore, the primary purpose of this study was to determine the joint association of weight status and PA on resting BP in children. The secondary purpose was to investigate the independent and joint association of weight status and PA on CRP levels in children. It was hypothesized that PA would attenuate BP and CRP in overweight children.

Methods

Subjects

Grade 5 students from 4 rural mid-Michigan communities (pop. < 11,000) were recruited to be part of a school-based intervention called (S)Partners for Heart Health. Data for this analysis were collected during preintervention assessments (Fall 2008); thus, this is considered a cross-sectional analysis. Of 370 students approached, 182
students assented and their parents/guardians consented to the study; 174 (71 males, 103 females) students with complete data for BP, PA, height, and body mass were used for the primary purpose of this analysis. Of the 174 children, 91 (39 males, 52 females) opted to provide a blood sample to have CRP measured and were used to examine the secondary purpose. The Michigan State University Institutional Review Board and each of the 4 school boards approved the study protocol.

**Habitual Free-Living PA**

PA was determined by a self-report question used in the Youth Risk Behavior Survey and asked “During the past 7 days how many days were you physically active for a total of at least 60 minutes per day (add up all the time you spend in any type of activity that increases your heart rate and makes you breathe hard some of the time)?” Responses included 0–7 days. Data were expressed as the number of days per week and percentage of participants reporting < 5 days per week (low PA) ≥ 5 days per week (high PA).

**Anthropometry**

Stature was measured without shoes, using a Shorr board (Shorr Production, Olney, MD) and body mass was determined using the Tanita BC-534 InnerScan Body Composition Monitor (Tokyo, Japan; US Service Center Arlington Heights, IL). BMI (weight in kg/height in m²) was calculated and weight status was classified using age- and sex-specific cut points. The BMI classification data were dichotomized into 2 groups: normal weight (P < 85th percentile) or overweight (P ≥ 85th percentile). Two subjects were underweight (< 5th BMI percentile) but were included in the normal weight group.

**Resting BP**

Resting BP was measured in accordance with standard procedures. Resting systolic (SBP) and diastolic (DBP) blood pressure was measured by sphygmomanometry after the subject was seated for 10 minutes. Three measurements were taken at 1-minute intervals, and the mean of the second and third values were used for data analysis.

**C-reactive Protein**

Blood samples were obtained in the nonfasted state by fingerstick and collected in heparinized capillary tubes. Blood sampling by fingerstick was chosen for reasons of compliance and feasibility. The blood sample was analyzed by the Cholestech LDX using the CRP cartridge according to the manufacturer’s procedures. A previous report has shown the correlation between fingerstick measurement and core laboratory measurement for CRP was 0.81. Subjects were asked about current or recent infection or illness, before blood sampling.

**Healthy Eating Index (HEI)**

Dietary intake was assessed with the Gladys Block Food Frequency Questionnaire for children. The HEI was used to control for dietary influences on blood pressure and CRP and provides an indication of the overall quality of the diet based on 10 components that are scored from 0–10 points each and then summed for an overall score (100 is the most desirable score).

**Statistical Analysis**

Descriptive statistics were calculated. Four weight/PA categories were formed by cross tabulation of normal/overweight, and low/high PA (Table 2). Group differences in BP and CRP were examined by ANCOVA, controlling for age, sex, HEI, and height. Associations among PA, BMI percentiles, BP, and CRP were computed by partial correlations. All analyses were conducted using SPSS version 16.0 and significance was set at \( P \leq 0.05 \).

**Results**

Physical characteristics of the sample are shown in Table 1. In total, 38% were overweight or obese and 49% did not meet PA recommendations. The prevalence of low PA did not differ between overweight and normal weight groups. Overall, the overweight group had higher SBP (\( P = 0.001 \)) and DBP (\( P = 0.15 \)) than the normal weight group (106.0 ± 1.1 mmHg vs. 99.1 ± 0.9 mmHg and 67.6 ± 0.9 mmHg vs. 65.9 ± 0.7 mmHg, respectively) and there was a significant positive correlation between BMI percentile and SBP (\( r = 0.36; \quad P = 0.001 \)) but not between BMI percentile and DBP (\( r = 0.16; \quad P = 0.06 \)). There were no significant differences in SBP or DBP between the high and low PA groups (102.0 ± 1.0 mmHg vs. 101.4 ± 1.1 mmHg; \( P = 0.70 \) and 66.8 ± 0.8 mmHg vs. 66.3 ± 0.8 mmHg; \( P = 0.68 \), respectively). SBP was significantly lower in the normal weight/high PA group (98.8 ± 1.2 mmHg) compared with both low and high PA groups within the overweight group (104.3 ± 1.6 mmHg and 107.5 ± 1.5 mmHg, respectively; Table 2). BP was not significantly different between the PA groups within either weight category.

Subjects (n = 91) included in the subanalysis possessed similar characteristics to those included in the full analysis. The correlation between BMI percentile and CRP was moderate (\( r = 0.48; \quad P = 0.001 \)), while a nonsignificant correlation was observed between PA and CRP (\( r = 0.01; \quad P = 0.96 \)). CRP was significantly higher in obese children (> 95th BMI percentile; 1.52 ± 1.20 mg/L) compared with normal weight (0.47 ± 1.12 mg/L) and overweight children (0.49 ± 1.24 mg/L; \( P = 0.001 \)). No significant difference was seen in CRP between PA groups (\( P = 0.87 \)) and PA did not modify the difference in CRP within weight categories (Table 3).
Table 1 Descriptive Statistics of the Population

<table>
<thead>
<tr>
<th></th>
<th>Males (n = 71)</th>
<th>Females (n = 103)</th>
<th>Total (n = 174)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Minimum–Maximuma</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>10.6 (0.5)</td>
<td>10.6 (0.5)</td>
<td>10.6 (0.5)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>143.3 (6.4)</td>
<td>144.4 (7.3)</td>
<td>144.0 (6.9)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>40.6 (10.8)</td>
<td>42.7 (11.8)</td>
<td>41.8 (11.4)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>19.7 (4.5)</td>
<td>20.2 (4.4)</td>
<td>20.0 (4.4)</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>101.9 (8.7)</td>
<td>101.2 (9.2)</td>
<td>101.5 (9.0)</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>66.8 (6.6)</td>
<td>66.4 (7.0)</td>
<td>66.6 (6.8)</td>
</tr>
<tr>
<td>Physical activity (days/week)</td>
<td>4.4 (2.2)</td>
<td>4.5 (2.1)</td>
<td>4.5 (2.1)</td>
</tr>
<tr>
<td>Healthy Eating Index</td>
<td>67.7 (9.6)</td>
<td>65.8 (9.7)</td>
<td>66.6 (9.7)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; PA, physical activity; wt, weight.

Note. Covariates (age, average height, sex, HEI score); P < 0.05.

* Values are minimum–maximum values in the total sample.

Table 2 Cross-Tabulated Weight/Physical Activity Groups for the Total Population; Values Are Mean (SE)

<table>
<thead>
<tr>
<th></th>
<th>Normal wt/high PA (n = 56)</th>
<th>Normal wt/low PA (n = 52)</th>
<th>Overweight/high PA (n = 33)</th>
<th>Overweight/low PA (n = 33)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>98.8 (1.2)*</td>
<td>99.4 (1.4)*</td>
<td>107.5 (1.5)</td>
<td>104.3 (1.6)</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>66.1 (1.0)</td>
<td>65.6 (1.1)</td>
<td>67.9 (1.2)</td>
<td>67.3 (1.3)</td>
</tr>
<tr>
<td>BMI percentile</td>
<td>48.4 (2.7)*</td>
<td>53.6 (3.0)*</td>
<td>92.8 (3.4)</td>
<td>93.6 (3.6)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>17.3 (0.4)*</td>
<td>17.5 (0.5)*</td>
<td>24.3 (0.5)</td>
<td>25.3 (0.5)</td>
</tr>
<tr>
<td>Physical activity (days/week)</td>
<td>6.2 (0.2)**</td>
<td>2.8 (0.2)</td>
<td>6.1 (0.2)**</td>
<td>2.6 (0.2)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; PA, physical activity; wt, weight.

Note. Covariates (age, average height, sex, HEI score); P < 0.05.

* Both Normal Weight groups significantly different than both Overweight groups.
** High PA groups significantly different than both Low PA groups.

Table 3 Cross-Tabulated Weight/Physical Activity Groups for the CRP Subgroup; Values Are Mean (SE)

<table>
<thead>
<tr>
<th></th>
<th>Normal wt/high PA (n = 29)</th>
<th>Normal wt/low PA (n = 27)</th>
<th>Overweight/high PA (n = 16)</th>
<th>Overweight/low PA (n = 19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRP (mg/L)</td>
<td>0.44 (1.18)*</td>
<td>0.49 (1.21)**</td>
<td>1.12 (1.24)</td>
<td>0.78 (1.24)</td>
</tr>
<tr>
<td>BMI percentile</td>
<td>51.0 (3.5)</td>
<td>47.0 (4.1)</td>
<td>96.5 (4.5)*</td>
<td>93.6 (4.5)*</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>17.4 (0.6)</td>
<td>16.9 (0.7)</td>
<td>25.8 (0.7)*</td>
<td>25.2 (0.7)*</td>
</tr>
<tr>
<td>PA (days/week)</td>
<td>6.3 (0.2)*</td>
<td>2.7 (0.2)</td>
<td>6.2 (0.3)*</td>
<td>2.6 (0.3)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; PA, physical activity; wt, weight; CRP, C-reactive protein.

Note. Covariates (age, sex, HEI score); P < 0.05.

* Normal Weight/High PA significantly different than both Overweight groups.
** Normal Weight/Low PA significantly different than the Overweight/High PA group.
# Both High PA groups significantly different than both Low PA groups.
+ Both Overweight groups significantly different than both Normal Weight groups.
Discussion

The results of this study indicate that weight status, but not PA, is positively related to BP and CRP in 9- to 12-year-old children. Although there were significant differences in SBP and CRP across the combined weight/PA groups, there were no significant differences in BP between the high and low PA groups within a weight category. Hence, the results do not support the hypothesis that PA attenuates BP or CRP in overweight and obese children.

Higher levels of both total fatness and visceral fatness have been shown to be positively correlated to CRP ($r = 0.64$), and ambulatory SBP (121.3 ± 12.6 vs. 106.6 ± 7.1 mmHg) and DBP (69.1 ± 5.7 vs. 63.7 ± 4.5) have been shown to be higher in obese subjects compared with lean controls. Results from NHANES 1988–2006 indicated that weight status was significantly associated with elevated BP in 8- to 12-year-old children with overweight boys (OR 1.54, CI 1.11–2.13) and obese boys and girls (OR 2.81, CI 2.13–3.71 and OR 2.55, CI 1.75–3.73, respectively) being significantly more likely to be prehypertensive than normal weight youth. The likelihood of being hypertensive was also significantly greater in both overweight and obese boys (OR 6.06, CI 2.73–13.44) and obese girls (OR 2.33, CI 1.31–4.13). Our results are consistent with these previous studies. Mean differences of 6.9 mmHg and 1.7 mmHg in SBP and DBP, respectively, were observed between the overweight and normal weight groups, and there was a significant positive correlation between BMI percentile and SBP ($r = 0.36$).

Previous studies have shown significant associations between CRP and relative weight ($r = 0.44$) in overweight/obese children, and also a positive correlation between CRP and SBP and DBP ($r = 0.498$). Our finding of a significant correlation between BMI percentile and CRP ($r = 0.48$) and the significantly higher levels of CRP in the obese group compared with both the normal weight and the overweight group (1.52 mg/L, 0.47 mg/L, and 0.49 mg/L, respectively) is consistent with previous studies. However, the correlation between CRP and SBP ($r = -0.02$) and DBP ($r = -0.11$) is inconsistent with previous studies. This finding may be due to our subjects representing the spectrum of body weight compared with the previous studies that included only overweight and obese children.

Although the positive effects of habitual physical activity and exercise on BP are clear in adults, the results are more variable and weaker in children. For example, cross-sectional studies indicate low correlations ($r < 0.25$) between physical activity and BP, which is consistent with our findings. Compared with the wealth of studies on PA and BP in children, few studies have examined the relationship between habitual PA and CRP in children and adolescents. Comparison of results in these studies is difficult due to varying methodology to assess PA (eg, accelerometer, questionnaire) and the use of flow mediated dilation as a measure of endothelial function instead of CRP levels. Studies have showed positive associations between PA and endothelial function. In contrast, our findings are consistent with 2 other studies that did not find a significant association. To our knowledge, no study has compared CRP levels by category of PA recommendations (60 min of MVPA per day, most days of the week). Our results indicate that CRP is not significantly different between those meeting or not meeting PA recommendations. This may be attributed to not enough minutes of moderate-to-vigorous PA in those achieving at least 5 days per week. By using more precise measures to quantify physical activity, detail regarding intensity can be used to better understand the relationship between PA and CRP in children.

As outlined previously, several studies have examined the univariate relationship between either adiposity and BP or PA and BP; however, no published study to our knowledge has examined the joint association of PA and weight status on BP in children. However, a recent study examined the joint association of PA and both BMI and measured body fat on CRP in children. The authors found a main effect for PA and both BMI and body fat, and an inverse association between PA and CRP. We did not find an association between PA and CRP in this study. A consideration that needs to be addressed when examining CRP in children and adolescents is that there is not a large variability in CRP, as seen in adults. This lack of variability may lead to nonsignificant findings, especially in cohorts that have low prevalence of overweight and obese subjects. This may continue to be problematic until child-specific cutpoints associated with increased risk of cardiovascular risk factors are derived for CRP.

A novel component of this study is that subjects were cross-tabulated into combined weight/PA groups using current recommendations (cut points) for both variables. The results did not support the hypothesis that PA attenuates the relationship between weight status, BP, and CRP in children as we have previously shown with aerobic fitness. Despite the null findings, it remains important to study the overweight and obese child who meets PA recommendations. In the current study, we found no significant difference in the percent of subjects who met the PA recommendation (eg, greater than 5 days/week) between weight groups. Longitudinal study of the overweight-active child is needed to better understand the long-term development of vascular health.

Two limitations of this study were the assessment of PA by self-report questionnaire and the use of BMI as a proxy for fatness. The age of the subjects in this study (mean age = 10.6 yrs) is the lower bound recommended for self-report. However, the use of BMI, and self-report PA has clinical utility since both are widely used in clinical practice. Another limitation of this study is that sex-specific analyses could not be conducted due to the sample size. Nutritional intake can have an effect on both CRP and BP, independent of changes in body weight. While HEI was controlled for in the analysis, further examination is warranted to better understand this relationship in both normal and overweight children.
In summary, weight status, specifically overweight and obesity, was shown to be positively associated with both BP and CRP in children; however, PA did not significantly attenuate BP or CRP within a weight category. Future studies are needed to better examine the utility of the national recommendations for PA on CVD risk factors, including BP, CRP, and other measures of vascular health (flow mediated dilation, ambulatory blood pressure). Although the PA recommendations were established with the expectation that they improve general health, their influence on health outcomes in overweight and obese children needs to be better understood as not all overweight and obese children are physically inactive.

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References


