Joint Association of Fatness and Physical Activity on Resting Blood Pressure in 5- to 9-Year-Old Children

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The purpose of this study was to determine the joint association of fatness and physical activity on resting blood pressure in children. Subjects included 157 children (age 5.5–9.5 years). Moderate-to-vigorous physical activity (MVPA, min/day), body fatness, and resting blood pressure were measured. Four categories were created by cross tabulation of high/normal levels of fatness and high/low levels of MVPA. There were significant differences in systolic blood pressure and mean arterial pressure across the fat/MVPA groups ($p < .05$). Regardless of participating in an acceptable level of MVPA, overfat children had higher resting systolic blood pressure than normal fat children. MVPA did not significantly attenuate blood pressure within a fat category.

It is well-documented that atherosclerosis begins at an early age (16,17,21). Such evidence includes fatty streak and plaque formation (16) and the emergence of adverse, traditional cardiovascular disease (CVD) risk factors such as elevated blood pressure (24). A very prominent risk factor for elevated blood pressure and other markers of early atherosclerosis is obesity (24,1,12,29). Despite the strong relationship between adiposity and blood pressure, we have recently shown that...
aerobic fitness attenuates the relationship between adiposity and CVD risk factors in youth (6,4,5,3). This concept of “Fat but Fit” was first proposed by Blair and colleagues (2) and subsequent studies have consistently demonstrated that aerobic fitness attenuates cardiovascular risk factors in adults (10,11) as well as in our studies in children and adolescents (6,4,5,3). It is not clear, however, if physical activity exerts a similar protective effect. While physical activity contributes to improvements in aerobic fitness, there are important distinctions that must be considered. Aerobic fitness, which is best represented by maximal oxygen consumption (VO$_{2max}$), involves the integrated efforts of the cardiovascular and respiratory systems along with the oxidative properties of skeletal muscle. Thus, aerobic fitness is a physiological trait. On the other hand, physical activity is a behavioral trait defined as any bodily movement produced by skeletal muscles that results in an increase in energy expenditure over resting levels (15). Although both are related to CVD risk factors, the mechanism by which they influence CVD risk factors differs (26).

Studies consistently demonstrate that overweight children are less active compared with normal weight youth; however, some overweight children do meet or exceed current physical activity recommendations (60 min of moderate-to-vigorous physical activity per day; 32,19). Few, if any, studies have examined how CVD risk factors are influenced in overweight children who meet or do not meet physical activity recommendations. Given that the current national guidelines for children call for achieving 60 min of moderate-to-vigorous physical activity (MVPA) per day, the concept of “Fat but Active” needs to be explored and better understood. In this paper, we cross-tabulated subjects into four fat/MVPA groups based on national recommendations and examined the joint association of fatness and MVPA on resting blood pressure in 5–9 yr old children. It was hypothesized that physical activity would attenuate blood pressure in overfat children.

**Methods**

**Participants**

Children (age 4–11 years) were recruited from a rural midwestern U.S. community (pop. 30,000) between the summers of 2003 and 2007 via word-of-mouth and an advertisement published in the local newspaper. Two hundred and fourteen children completed at least one visit. Data on 157 children (78 males and 79 females, aged 5.5–9.5 years) who had complete data for blood pressure, physical activity, and body composition were used in this analysis. This study was approved by the University of Nebraska at Kearney Institutional Review Board. Informed consent was obtained from all participating parents and assent was obtained from participating children.

**Anthropometry**

Stature and body mass were measured according to standard procedures (13). Stature was measured to the nearest 0.1 cm using a wall-mounted stadiometer, and body mass was measured to the nearest 0.1 kg using a standard balance beam scale. Body mass index (BMI) was calculated using the following equation: body mass in kg/stature in m$^2$. 

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Dual Energy X-ray Absorbtimetry (DXA)

Whole-body DXA scans were performed with the subject in light clothing while lying supine using a Lunar DPX-L densitometer (Lunar Radiation Corporation, Madison, WI, USA). Percent body fat was determined using the pediatric medium scan mode (software version 1.5d). The Lunar DPX-L densitometer has previously been cross-validated using the pig carcass in the pediatric weight range (22). Reliability between scans was achieved using a phantom calibration.

Measurement of Resting Blood Pressure

Resting blood pressure was measured in accordance with standard procedures and recommendations (28). Appropriate cuff size was determined by measuring the circumference of the right upper arm at its largest point. Resting systolic (SBP) and diastolic (DBP) blood pressure were measured by manual sphygmomanometry after the subject was seated for 10 min. Three measurements were taken at 1-min intervals, and the mean of the three values were used for data analysis. Mean arterial pressure (MAP) was calculated as: (SBP-DBP/3) + DBP.

Habitual Physical Activity

Research participants were asked to wear an Actigraph (model #AM7164, Fort Walton, FL) for seven consecutive days. The Actigraph is a small (5.1 × 3.8 × 1.5 cm), light weight (45g) uniaxial accelerometer designed to detect acceleration ranging in magnitude from 0.05 to 2.00 G with a frequency response of 0.25–2.50 Hz. For the current study, a 30-s epoch was used. Children were required to wear the Actigraph for at least four full days to be included in the analysis. To be considered a full day, the monitor had to be worn for at least 480 min (8 hr) with fewer than three 20-min bouts of nonwear time (9). If the criteria were not achieved, that particular day was excluded from the data analysis. Parents/guardians were asked to fill out a daily log sheet in conjunction with each child wearing the Actigraph to determine when the monitor was removed for bathing, swimming or forgotten. To ensure accuracy, each day of the minute-by-minute physical activity data were downloaded and manually checked against the daily physical activity log sheet by the one of the investigators (JT).

The Actigraph data were processed to estimate the average minutes of MVPA per day. The cutpoint used as a threshold for MVPA was developed through a calibration study that employed direct observation as the criterion measure (31). Children were observed while going through a series of free-living activities and the cutpoint was determined using receiver operator characteristic (ROC) curves that identified the count that most accurately corresponded with the observed transition to moderate physical activity (the threshold of MVPA). The process yielded a value of 2172 counts/min with reported sensitivity and specificity of 95.9 and 87.6, respectively (31).

Statistical Analysis

Descriptive statistics were calculated for all variables. Categories were created using recommendations for physical activity and fatness. The physical activity categories
were created based on whether participants met the recommended level of 60 min of MVPA per day (27). The fatness categories were based on the FITNESSGRAM cut points of 25% body fat for males and 30% for females, which were shown to be indicative of an increased risk of being in the highest quintile for blood pressure and serum lipoproteins (30). The participants were divided into four fatness/activity categories (combination of high/normal fatness and high/low MVPA) for comparison. Group differences in blood pressure were determined by ANCOVA, controlling for age, sex, and height. Data processing was handled in SAS 9.1 but all inferential analyses were conducted using SPSS version 15.0.

Results

Physical characteristics of the participants are shown in Table 1. Values for body size, blood pressure, and MVPA were similar between males and females, with the exception of percent body fat, which was significantly higher in females. The mean values for stature were slightly above the 50th percentile for both males and females, whereas the mean body mass approximated the 70th percentile, and the mean BMI approximated the 53rd percentile of the Centers for Disease Control (CDC) growth charts. The mean values for systolic blood pressure and diastolic blood pressure were considered normotensive based upon the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents (28). In total, 33.8% were overfat and 49.0% did not meet physical activity recommendations.

The adjusted means (SE) for blood pressure across the fat/MVPA groups are shown in Table 2. The percentage of subjects in each group was as follows: normal

<table>
<thead>
<tr>
<th>Table 1 Physical Characteristics of the Sample</th>
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</thead>
<tbody>
<tr>
<td><strong>Males (n = 78)</strong></td>
</tr>
<tr>
<td>Age (yrs)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
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<tr>
<td>BMI (kg/m²)</td>
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<tr>
<td>BMI z-score</td>
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<tr>
<td>Body Fat (%)</td>
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<tr>
<td>SBP (mmHg)</td>
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<tr>
<td>DBP (mmHg)</td>
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<tr>
<td>MAP (mmHg)</td>
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<td>MVPA (min/d)</td>
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*P < 0.05 for sex difference
Values are mean (SD) for males and females and mean (SD) and minimum-maximum values in the total sample.
Fatness, Physical Activity, and Blood Pressure

Fatness, Physical Activity, and Blood Pressure

Of the 103 normal fat subjects, 43% did not meet the physical activity recommendation whereas 61% of the 54 high fat subjects did not meet the physical activity recommendation. Overall, the high fat group had higher systolic and diastolic blood pressure (106.6 ± 8.2 mmHg and 72.8 ± 6.0 mmHg, respectively) than the normal fat group (101.5 ± 8.2 mmHg and 68.7 ± 7.7 mmHg, respectively). Although the high MVPA group as a whole had lower systolic blood pressure, diastolic blood pressure, and MAP than the low MVPA group, significance was not reached ($p = 0.13–0.24$). There were significant differences in systolic blood pressure and MAP across the fat/MVPA groups. There was a trend seen in that the high MVPA groups in both fatness categories had lower systolic blood pressure, diastolic blood pressure, and MAP than their lower MVPA counterparts. There were no significant differences in blood pressure between the high and low MVPA groups within either fat group.

The continuous relationships between blood pressure and physical activity and blood pressure and body fat, and the relationship between body fat and physical activity were also analyzed. The correlations between physical activity and all measures of blood pressure (systolic, diastolic, and mean arterial pressure) were inverse and nonsignificant, both when controlled for age, sex, and height ($r=-0.145$ to -0.077) and when controlled for age, sex, height, and body fat ($r=-0.111$ to -0.048). Physical activity and body fat were inversely related ($r = .198$, ns). The correlations between body fat and all measures of blood pressure (systolic, diastolic, and mean arterial pressure) were positive and nonsignificant, both when controlled for age, sex, and height ($r = .219–0.288$) and when controlled for age, sex, height, and physical activity ($r = .211–0.276$).

### Table 2  Vascular, Physical Activity and Fatness Characteristics Per Activity/Fatness Group

<table>
<thead>
<tr>
<th>Activity/Fatness Group</th>
<th>Normal FAT/High MVPA ($n = 59$)</th>
<th>Normal FAT/Low MVPA ($n = 44$)</th>
<th>High FAT/High MVPA ($n = 21$)</th>
<th>High FAT/Low MVPA ($n = 33$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP (mmHg)</td>
<td>101.3 (0.9)</td>
<td>102.9 (1.1)</td>
<td>105.3 (1.6)</td>
<td>106.0 (1.3)</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>68.9 (0.88)</td>
<td>69.7 (1.0)</td>
<td>70.8 (1.5)</td>
<td>72.2 (1.2)</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>79.7 (0.7)</td>
<td>80.8 (0.8)</td>
<td>82.3 (1.2)</td>
<td>83.4 (1.0)</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>21.1 (4.5)</td>
<td>22.0 (4.5)</td>
<td>31.4 (6.5)</td>
<td>35.8 (5.2)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>15.4 (1.3)</td>
<td>15.4 (1.1)</td>
<td>17.5 (2.9)</td>
<td>18.8 (3.0)</td>
</tr>
<tr>
<td>MVPA (min/day)</td>
<td>90.6 (39.1)</td>
<td>42.4 (11.5)</td>
<td>82.5 (27.5)</td>
<td>38.6 (13.9)</td>
</tr>
</tbody>
</table>

Normal Fat/High MVPA group significantly different SBP than both High Fat groups ($P < 0.05$)
Normal Fat/High MVPA group significantly different MAP than the High Fat/Low MVPA group ($P < 0.05$)
Normal Fat/Low MVPA group significantly different MAP than the High Fat/Low MVPA group ($P < 0.05$)
Values are mean ($SE$) for each group.
Discussion

Previous investigations have examined the relationship between adiposity and blood pressure (23), in addition to physical activity and blood pressure (8) in youth. To our knowledge, this is the first paper to examine the joint association of physical activity and adiposity on blood pressure in youth. Overall, the results of this study indicate that excess adiposity, but not physical activity, is related to higher blood pressure. Although there were significant differences in systolic blood pressure and MAP across the fat/MVPA groups, there were no significant differences in blood pressure between the high and low MVPA groups within a fat group. Hence, the results do not support the hypothesis that physical activity attenuates blood pressure in children with high levels of body fat.

Our results are consistent with the literature showing that higher adiposity is associated with higher blood pressure (24,1,12,29,23). We found mean differences of 5.1 mmHg and 4.1 mmHg in systolic blood pressure and diastolic blood pressure, respectively between overfat and normal fat youth (classified by FITNESSGRAM standards). Results from the Multiple Risk Factor Intervention Trail have shown that the effect of a 5 mmHg reduction in SBP on mortality due to coronary heart disease, cardiovascular disease, and all causes decreases mortality by 10.5%, 11.3%, and 7.9%, respectively (25). A recent analysis of data from the National Health and Nutritional Examination Survey (NHANES) compared blood pressure among children and adolescents from three time periods between 1988–2006 (18). Overweight and obesity were significantly associated with an elevated blood pressure. The results for physical activity are also in general agreement with previous work in this area. Several papers show that there is a weak to moderate correlation \( r < .30 \) between physical activity and blood pressure (27,7). This relationship strengthens though when focusing on those with hypertension, instead of the whole spectrum of blood pressure values (20). Few studies have compared blood pressure by children who meet or do not meet current physical activity recommendations (14).

The unique aspect of this paper is that subjects were cross-tabulated into fat/MVPA groups using current recommendations for both variables. Although it is often assumed that overfat children are inactive, we found that 39% of the overfat subjects actually met the physical activity recommendations (e.g., 60 min per day of MVPA) compared with 57% of the normal fat subjects \( p = .031 \). Hence, one cannot assume that normal weight children are active or that obese children are inactive. Given this premise it seems important to consider both variables when assessing the CVD risk profile of children. However, the results of this study do not support the hypothesis that physical activity attenuates the relationship between fatness and blood pressure in children. We did, however, observe a trend across the four fat/MVPA groups. The only significant differences were found between normal fat/high MVPA group and both high fat/MVPA groups for SBP and the high fat/low MVPA group for MAP. In addition, the normal fat/low MVPA group had significantly lower MAP than the high fat/low MVPA group.

A major goal of the study was to examine whether physical activity moderates the association of fatness on blood pressure by comparing overweight youth that either met or did not meet MVPA guidelines. Although the high fat/high MVPA group had slightly lower mean blood pressure values compared with their high fat/low MVPA counterparts, the differences did not reach statistical significance
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(p = 0.48–0.74). In addition, although not significantly different, the high fat/high MVPA group had higher blood pressure compared with the normal fat/low MVPA group. Despite the null findings within a fat category, it remains important to further study the overfat child who meets physical activity recommendations. For example, what happens in these children if they continually meet the physical activity recommendation while remaining overfat? This question needs to be addressed in longitudinal studies involving a larger sample of overweight and obese children and adolescents. Likewise, those children who are normal weight/fatness but do not meet the physical activity recommendation should not be ignored given the general positive influence of a physically active lifestyle on overall health and well-being.

One reason that we may not have seen significant differences between high and low MVPA groups within the overfat category is that the mean MVPA minutes in the high fat/low MVPA group was 39 min/day. It may be that the differences in blood pressure do not emerge until much lower levels of MVPA (e.g., <15 min/d) are reached. Despite our findings, continued examination of this association remains important since some children are meeting the guidelines for daily physical activity but are overweight. From a clinical perspective, it is important to consider that when these children are classified as overweight in a clinician’s office, it may be assumed that they are inactive and hence told that they need to increase their physical activity level even though they meet the guidelines. While the current national guidelines are meant to improve general health and not necessarily cause weight loss, they are still the standard used by most clinicians. This can lead to frustration on the part of the child since meeting the recommendation is not resulting in visible changes that are rewarded by positive feedback from the clinician. This feeling of “why bother” on the part of the child may then lead to additional weight gain, hypertension, and cardiovascular dysfunction.

One limitation of this study is that sex-specific analyses could not be conducted due to the sample size. Among the fatness and MVPA groups, a number of sex differences became apparent. For example, 60% of the boys met the current recommendations compared with 42% of the girls in the study (p = .026). There were no differences in the number of males or females who were high vs. low fat (p = .739). There were significant (p < .05) differences in the gender make up of the high fat/high MVPA group (71% male, 29% female) and the high fat/low MVPA group (39% male, 61% female). In light of these differences, we controlled for sex in the statistical analysis. Future studies examining the joint association of fatness and physical activity on CVD risk factors should examine sex differences.

As previously mentioned, a unique aspect of the current study is the approach of cross-tabulating youth into fatness and physical activity groups using established health-related cut points. Another major strength of this study was the use of DXA to measure percent body fat and objectively assessing physical activity via accelerometry. Many epidemiological or clinical studies rely on self-report physical activity measures and body mass index.

In summary, the results indicate a clear pattern across fat/MVPA groups. Children in the high fat/low MVPA group had the highest blood pressure while those of normal fatness levels who met the national physical activity guidelines (>60 min/day) had the lowest blood pressure. MVPA did not significantly attenuate blood pressure within a fat category. While there was no attenuation of blood pressure by MVPA in this sample of children, future studies are needed to better examine the
joint association of physical activity and fatness on measures of vascular health. Investigating the changes in vascular health occurring in overfat/obese children who are meeting the recommendations for MVPA will allow researchers and clinicians to better tailor recommendations to specific subgroups (overfat/active vs. normal fat/inactive) as opposed to a ‘one-size-fits-all’ approach to physical activity counseling.

Acknowledgments

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References


