Blood Pressure and Physical Fitness in Children

ALBERT HOFMAN, HEATHER J. WALTER, PATRICIA A. CONNELLY, AND ROGER D. VAUGHAN

SUMMARY The association between physical fitness and blood pressure was studied in 2061 children selected from all fourth graders in 44 elementary schools in the New York City area. Their blood pressure and physical fitness were measured on two consecutive examinations 1 year apart. Systolic and diastolic blood pressure were highest in children with poor physical fitness. The change in physical fitness between the 2 examination years was related to the change in systolic and diastolic blood pressure (i.e., children with a decline in physical fitness showed the largest rise in blood pressure). These observations suggest that the level of systolic and diastolic blood pressure in children is associated with the level of physical fitness. They also indicate that change in blood pressure in childhood may be related to change in physical fitness. (Hypertension 9: 188-191, 1987)

KEY WORDS • hypertension • blood pressure • physical fitness • childhood • epidemiology

BLOOD pressure rises with age. Of the total lifetime increase in systolic blood pressure, about two thirds occurs in childhood, but the determinants of this rise early in life are still largely unknown. Physical exercise has been suggested to lower blood pressure in hypertensive adults, and some observations suggest that the same may be true for adolescents. However, only limited evidence is as yet available about an etiological relation between physical fitness and blood pressure in children.

We present the results of a study of the association between physical fitness and blood pressure in 2061 children living in the New York City area.

Subjects and Methods

Population

The source population for this study comprised all 4105 students in the fourth grade of 44 elementary schools in New York. Six of these school districts, with 1822 children, were located in Westchester County, and one school district, with 2283 children, was in the Bronx. The average age of these children was 9.1 years, and 52% of them were boys; 58% of the children were white, 27% black, 12% Hispanic, and 3% of other origin (primarily Asian or Pacific). The 1983 median family income was $55,904 in Westchester County and $22,126 in the Bronx. The population in the Bronx, as well as in Westchester County, has been described in detail elsewhere.

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in the intervention schools and 668 in the control schools) in whom informed consent was obtained and in whom blood pressure and physical fitness were measured during both the examinations at baseline and after 1 year. The other subjects either were absent on the examination day, had migrated out of the district in the course of the study, or they or their parents declined consent to participate. The proportion of non-participants was similar in intervention and control children.10,11

Measurements

The examinations were conducted by trained personnel in the schools on weekdays between 0900 and 1500. Systolic and diastolic blood pressure were measured with a standard sphygmomanometer (W.A. Baum, Copiague, NY, USA) on the right arm at heart level, with the subject seated. Three readings were obtained, and the average of the second and the third reading was used in the analyses. Diastolic blood pressure was based on the fourth Korotkoff sound. To measure physical fitness, the protocol for the Harvard step test13 was modified for use among younger subjects. The children stepped up and down a 13-in. platform 30 times a minute for 4 minutes. Pulse rate was measured at 1, 2, and 3 minutes postexercise. These three pulse rates were summed, and this postexercise sum of pulses was used as a measure of physical fitness. A high sum of pulses corresponds to poor physical fitness.13,14 The exercise test was performed after the blood pressure measurement. Body weight and height were measured using a standard medical balance beam scale with a rigid vertical rod.

Data Analysis

Our data-analytic approach was twofold. First, we investigated the cross-sectional association of physical fitness (as measured by the postexercise sum of pulse rates) and blood pressure at the examination at baseline and after 1 year. We divided the subjects into four categories of the sum of pulse rates, according to quartiles. At baseline, the cut-off points for boys were 268, 303, and 335 beats/3 min, and for girls were 290, 328, and 362 beats/3 min. We computed the average change in systolic and diastolic blood pressure by category of the sum of pulse rates. Furthermore, we performed multiple linear regression with change in systolic and diastolic blood pressure as the outcome variables and change in the sum of pulse rates as the determinant, with age, race, area of residence, ponderosity index, resting pulse rate at baseline, change in ponderosity index, and intervention status added to the regression model.

Results

Some characteristics of the study population at the baseline examination are given in Table 1. Correlation coefficients of systolic and diastolic blood pressure with body height, weight, resting pulse rate, and postexercise pulse rate are given in Table 2. The average values of systolic and diastolic blood pressure at the baseline examination increased by category of the postexercise sum of pulse rates (Table 3). This finding applied to boys as well as to girls. A regression analysis confirmed these findings (Table 4). All coefficients of linear regression of blood pressure on sum of pulse rates were positive and significantly different from zero.

The average change in systolic and diastolic blood pressure between examinations is given by category of change in sum of pulse rates in Table 5. Children who

<table>
<thead>
<tr>
<th>Table 1. Characteristics at Baseline Examination</th>
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<tbody>
<tr>
<td>Characteristic</td>
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<tr>
<td>----------------------------------------</td>
</tr>
<tr>
<td>No. of subjects</td>
</tr>
<tr>
<td>Mean age (yr)</td>
</tr>
<tr>
<td>Mean systolic BP (mm Hg)</td>
</tr>
<tr>
<td>Mean diastolic BP (mm Hg)</td>
</tr>
<tr>
<td>Mean height (cm)</td>
</tr>
<tr>
<td>Mean weight (kg)</td>
</tr>
<tr>
<td>Whites (%)</td>
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<tr>
<td>Blacks (%)</td>
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<tr>
<td>Hispanics (%)</td>
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</table>

Standard deviation is shown in parentheses.

<table>
<thead>
<tr>
<th>Table 2. Correlation Coefficients of Various Characteristics at Baseline with Systolic and Diastolic Blood Pressure</th>
</tr>
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<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Body height</td>
</tr>
<tr>
<td>Body weight</td>
</tr>
<tr>
<td>Resting pulse rate</td>
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<tr>
<td>Postexercise pulse rate</td>
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</table>

SBP = systolic blood pressure; DBP = diastolic blood pressure.
did the largest increase in sum of pulse rates (i.e., had a decline in physical fitness) showed the largest increase in systolic blood pressure. The pattern was less clear for diastolic pressure. Table 6 presents the coefficients of linear regression of change in systolic and diastolic blood pressure on change in sum of pulse rates. All coefficients were positive and three of them were significantly different from zero.

Discussion

The main finding in this study is that blood pressure in children appears to be associated with level and change in physical fitness. Before we take this finding as evidence for an etiological relation of physical condition and blood pressure, some problems of our study must be mentioned.

The source population of this study comprised all 4105 fourth-graders in seven school districts in New York, and 2061 of them (50%) were included in the present analysis. We consider it unlikely that the observed associations have resulted from selective refusal to participate in the study. This is substantiated by the observation that the average levels of blood pressure and physical fitness of the children who only took part in the baseline examination were not materially different from those who participated in both examinations. Also, the results of the analysis were very similar for baseline and 1-year follow-up. Although the data were collected in an intervention study, we analyzed it as an observational study because of the absence of an intervention effect of physical fitness. A separate analysis of the children in the intervention schools and the control schools yielded virtually identical results. This was also borne out by the nonsignificant regression coefficients of intervention status.

We took the postexercise sum of pulse rates, as obtained with the Harvard step test, as a measure of physical fitness. The step test correlates reasonably well with maximum oxygen consumption as an index for physical fitness and has therefore been used in many epidemiological studies, although only limited evidence is available concerning its validity in chil-

<table>
<thead>
<tr>
<th>Category</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>SBP (mm Hg)</td>
</tr>
<tr>
<td>I (improved)</td>
<td>263</td>
<td>-1.9 ± 8.8</td>
</tr>
<tr>
<td>II</td>
<td>261</td>
<td>-1.1 ± 7.8</td>
</tr>
<tr>
<td>III</td>
<td>260</td>
<td>0.9 ± 8.2</td>
</tr>
<tr>
<td>IV (worsened)</td>
<td>263</td>
<td>2.8 ± 8.4</td>
</tr>
</tbody>
</table>

Values are means ± SD. Category of change in sum of pulse rates is based on quartiles: -30, 3, and 35 beats/3 min/yr for boys and -20, 10, and 44 beats/3 min/yr for girls.
A lack of complete agreement tends to lead to underestimation of a relation between blood pressure and physical fitness, rather than to a spurious association. A conceptual problem results from the lack of information about the relation of physical fitness and physical activity. The findings in the present study only have bearing on physical fitness, and inference concerning physical activity is presented with caution.

It might be argued that our findings reflect the often observed positive association between resting pulse rate and blood pressure, because of a possible relation between resting and postexercise pulse rate. In this study the correlation coefficient of resting and post-exercise pulse rate amounted to 0.50 for boys and 0.40 for girls. However, adding resting pulse rate to the models for linear regression of blood pressure on post-exercise sum of pulse rate did not materially change the coefficients.

The possibility that a confounding variable may be operative must be considered. This refers in particular to obesity, because it is a determinant of blood pressure and it may also be related to physical fitness. However, after adjustment for differences in ponderosity index, the strong relation between physical fitness and blood pressure remained, although the regression coefficients decreased in magnitude. We are therefore confident that our findings are not the result of confounding by obesity.

Our cross-sectional analysis confirms a report of Fraser et al., who studied a smaller group of children. Our finding that change in physical fitness is associated with change in blood pressure adds to the existing evidence in adults of an association between physical fitness and blood pressure. Whether these findings have any relevance for the prevention of hypertension awaits further investigation, in particular through intervention studies.

In summary, our observations in children are consistent with the view that there is an association between the level of physical fitness and blood pressure and that change in physical fitness in children is associated with change in blood pressure.

Acknowledgments

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