Cardiovascular Response to Mental Stress and to Handgrip in Children

The Role of Physical Activity

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SUMMARY

Cardiovascular responses to sympathetic stimulation may be altered in the early phases of life of subjects with a family history of hypertension. The possible influence of physical activity on adrenergic modulation in children is still not well known. In this study we evaluated, in a group of 162 11-year-old children from a secondary school near Naples, blood pressure and heart rate measured 4 times at 3-week intervals at rest and during adrenergic system stimulation by mental arithmetic stress and isometric exercise. Children were divided into sedentary and physically active groups according to the levels of a Saltin modified questionnaire. Family history of hypertension was also investigated. Systolic and diastolic blood pressure at rest were slightly higher in the sedentary group at each control (107/75±11/11 vs 105/73±11/11 mmHg at the first and 100/70±14/14 vs 98/69±9/9 at the last control); heart rate in the same group was higher as well (91±11 vs 87±12 beats/min, p<0.02 at the first and 80±9 vs 77±11 at the last control).

Systolic and diastolic blood pressure increased by 7/15% during mental stress and by 23/45% during isometric exercise in the sedentary group. The corresponding blood pressure increases in the physically active group were 6/12% and 20/40%, respectively. These responses were independent of sex, body weight and family history of hypertension. These results support the hypothesis that regular physical activity in young adolescents only mildly influences resting blood pressure and cardiovascular responses during the stimulation of the sympathetic nervous system.

Key Words: Blood pressure, Physical activity, Sympathetic nervous system, Mental stress, Isometric exercise.

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Received for publication March 15, 1990.
Accepted February 18, 1991.
MANY studies have been performed in the last decade to investigate the pathophysiology of arterial hypertension in the early phases of life.\textsuperscript{1,2} There are many reports indicating that the sympathetic nervous system plays a central role.\textsuperscript{3,4} It has been found to be frequently altered in children or young adults at high risk of hypertension, particularly those with a positive family history.\textsuperscript{5–10}

Less clear, on the other hand, is the role of regular physical activity on blood pressure both at rest and during stimulation of the adrenergic nervous system,\textsuperscript{11–13} despite evidence that adolescents practicing sports have a lower incidence of hypertension in mid-life.\textsuperscript{14,15} We studied a sample of normotensive children, either physically active or sedentary, in order to compare their blood pressure and heart rate, both at rest and during stimulation of the adrenergic nervous system.

**Subjects and Methods**

The investigations were performed in a secondary public school in Grumo Nevano, a suburb on the northern periphery of Naples. The study group consisted of 162 (102 M, 60 F) 11-year-old children attending the sixth grade class. They were followed up over a 3-month period, when 4 visits at 3-week intervals were made to the school. The examinations were carried out in the morning between 8.30 a.m. and 12.30 p.m. in an isolated comfortable room at 25°C. Sitting and standing systolic and diastolic blood pressure (BP), measured twice by a random-zero machine\textsuperscript{16} with a pediatric cuff (16 × 10 cm), and heart rate (HR) were evaluated at each visit. Measurements were performed by a group of doctors from our Blood Pressure Unit, previously certified and trained to obtain an inter-observer difference below 5%. Children rested in a quiet and warm room at 25°C for 10 min before measurements.

Height and body weight were measured at the first visit and body mass index (BMI) was calculated as body weight/height\textsuperscript{2} (kg/m\textsuperscript{2}). Physical activity was investigated using the Saltin modified questionnaire:\textsuperscript{17}

- **level 1:** spending most leisure time watching television, going to theatre or cinema or in other sedentary activities only
- **level 2:** spending time occasionally in light physical activities (i.e., walking, cycling, table tennis)
- **level 3:** practicing sports such as soccer, swimming, gymnastics, tennis or skating for less than 3 hours a week
- **level 4:** practicing sports such as skating, swimming, soccer, basketball, tennis, etc. on a regular basis, training several times a week.
A questionnaire for the evaluation of family history of hypertension was also completed by the children along with their parents: it was considered positive when at least one of the parents or two of the closest relatives were hypertensive.

In the third visit children were asked to carry out a mental arithmetic exercise by performing several calculations of increasing difficulty at 5-sec intervals for up to 270 sec, meanwhile a metronome was producing a standard noise: blood pressure was measured at baseline, after 90, 180 and 270 sec during the stress and at 90 sec in the following recovery phase. In the third follow-up children also provided a 24-hr urine collection for the measurement of catecholamine excretion. On the fourth visit they performed an isometric exercise (handgrip), squeezing a partly inflated sphygmomanometer cuff with the dominant hand for a period of 2 min. They were asked to sustain 60% of a previously determined maximum contraction. Measurements of BP and HR were performed at 30-sec intervals during the test and up to 2 min in the following recovery phase.

**Biochemical methods:** Twenty-four-hour urinary catecholamine (norepinephrine+epinephrine) excretion was measured by a fluorimetric assay.

**Statistical analysis:** Data are expressed as mean±standard deviation (mean±SD). Statistical significance was evaluated by Multivariate Analysis of Variance (Manova) for repeated measures, using the SPSS statistical package. The comparisons of individual time points were performed only when overall Manova interaction was significant.

### Results

The responses to the questionnaire for physical activity of the children are shown in Table I. It is noteworthy that boys more frequently than girls spend their leisure time practicing sports. In fact more than 60% of the males ranked as level 3 or level 4 and only 15% ranked as level 1. In the female group, on the other hand, only 38% ranked as level 3 or level 4 of physical activity and more than 50% ranked as level 1, which is almost com-

<table>
<thead>
<tr>
<th>Level</th>
<th>Male n°</th>
<th>Female n°</th>
<th>Total n°</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>32</td>
<td>46</td>
</tr>
<tr>
<td>2</td>
<td>26</td>
<td>6</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
<td>9</td>
<td>41</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>13</td>
<td>43</td>
</tr>
</tbody>
</table>
Table II. Sitting and Standing Systolic (SBP) and Diastolic (DBP, fourth and fifth phase) Blood Pressure and Heart Rate (HR) in 162 11 Year Old Children at the First Control

<table>
<thead>
<tr>
<th></th>
<th>Sitting</th>
<th></th>
<th>Standing</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SBP</td>
<td>DBP (IV)</td>
<td>DBP (V)</td>
<td>HR (beats/</td>
</tr>
<tr>
<td></td>
<td>(mmHg)</td>
<td>(mmHg)</td>
<td>(mmHg)</td>
<td>min)</td>
</tr>
<tr>
<td>Group 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107.2</td>
<td>74.6</td>
<td>61.6</td>
<td>91.0</td>
</tr>
<tr>
<td></td>
<td>(11)</td>
<td>(11)</td>
<td>(13)</td>
<td>(11)</td>
</tr>
<tr>
<td>Males</td>
<td>107.6</td>
<td>74.8</td>
<td>62.8</td>
<td>86.6</td>
</tr>
<tr>
<td></td>
<td>(10)</td>
<td>(7)</td>
<td>(11)</td>
<td>(7)</td>
</tr>
<tr>
<td>Females</td>
<td>106.7</td>
<td>74.4</td>
<td>60.4</td>
<td>95.8</td>
</tr>
<tr>
<td></td>
<td>(12)</td>
<td>(13)</td>
<td>(15)</td>
<td>(12)</td>
</tr>
<tr>
<td>Group 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>104.7</td>
<td>72.8</td>
<td>59.7</td>
<td>86.8*</td>
</tr>
<tr>
<td></td>
<td>(11)</td>
<td>(11)</td>
<td>(15)</td>
<td>(12)</td>
</tr>
<tr>
<td>Males</td>
<td>103.9</td>
<td>72.2</td>
<td>59.7</td>
<td>85.0</td>
</tr>
<tr>
<td></td>
<td>(12)</td>
<td>(12)</td>
<td>(16)</td>
<td>(12)</td>
</tr>
<tr>
<td>Females</td>
<td>107.0</td>
<td>74.5</td>
<td>59.8</td>
<td>91.6</td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>(9)</td>
<td>(13)</td>
<td>(11)</td>
</tr>
</tbody>
</table>

Significance vs group 1: * < 0.02. Mean ± SD.

Group 1: sedentary, Group 2: physically active.

pletely sedentary. It was decided to pool the data from subjects in levels 1 and 2 in the “sedentary” group (Group 1) and those in levels 3 and 4 in the “physically active” group (Group 2). Body weight was slightly higher in group 1 than in group 2 (41.1 ± 8 vs 39.9 ± 8 kg, BMI 19.9 ± 3 vs 19.0 ± 3 kg/m²). It is noteworthy to remark that females were more numerous in group 1 and that they were heavier than males in both the sedentary (43 ± 10 vs 39 ± 7 kg, BMI 20.6 ± 4 vs 19.1 ± 2.5 kg/m²) and physically active groups (43 ± 9 vs 39 ± 7 kg, BMI 20.2 ± 3 vs 18.6 ± 2 kg/m²), according to the puberal maturation that at this age is more advanced in females than in males. For this reason the BP and HR data will be given both as totals and according to sex.

Positive family history for arterial hypertension was equally present in both groups: it was detected in 21 (25%) physically active and in 21 (27%) sedentary children.

Systolic and diastolic BP at the first control were similar in the 2 groups (107/74 ± 11/11 vs 105/73 ± 11/11 mmHg in the sedentary and physically active group, respectively). HR of the sedentary group was on the other hand significantly higher (91 ± 11 vs 87 ± 12 beats/min, p < 0.02) (Table II).

A marked reduction of BP and HR was observed in both groups at the last visit (100/70 ± 14/14 mmHg in the sedentary and 98/69 ± 9/9 in the phys-
Table III. Sitting and Standing Systolic (SBP) and Diastolic (DBP, fourth and fifth phase) Blood Pressure and Heart Rate (HR) in 162 11 Year Old Children at the Fourth Control

<table>
<thead>
<tr>
<th></th>
<th>Sitting</th>
<th>Standing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SBP (mmHg)</td>
<td>DBP (IV) (mmHg)</td>
</tr>
<tr>
<td>Group 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.3 (14)</td>
<td>70.5 (11)</td>
</tr>
<tr>
<td>Males</td>
<td>99.3 (11)</td>
<td>71.9 (8)</td>
</tr>
<tr>
<td>Females</td>
<td>101.3 (16)</td>
<td>69.0 (14)</td>
</tr>
<tr>
<td>Group 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>97.6 (9)</td>
<td>69.0 (9)</td>
</tr>
<tr>
<td>Males</td>
<td>97.3 (9)</td>
<td>68.1* (9)</td>
</tr>
<tr>
<td>Females</td>
<td>98.5 (11)</td>
<td>71.5 (9)</td>
</tr>
</tbody>
</table>

Significance vs group 1: *p<0.05. Mean±SD.

Group 1: sedentary, Group 2: physically active.

Fig. 1. Systolic and diastolic blood pressure (top) and heart rate (bottom) in sedentary (hatched bars and closed circles) and physically active (open bars and open circles) 11-year-old children during mental arithmetic test and in the following recovery phase (total sample in the middle; male group on the left; female group on the right).
ically active group); corresponding HRs were 80±9 and 77±11 beats/min (Table III).

Cardiovascular responses to mental arithmetic exercise are shown in Fig. 1. Systolic and diastolic BP throughout the test were slightly lower in the physically active group, but a statistically significant difference was not always detectable. HR during the test was also similar in the two populations. Percent increase of systolic and diastolic BP was 7/15% in the sedentary group and 6/12% in the other. The response pattern was similar in both male and female subgroups.

During isometric exercise, BP and HR sharply increased in both sedentary and physically active groups, percent peak increases of BP being 23/45% and 21/40%, respectively. No sex-mediated difference in the 2 groups was shown in the pattern of cardiovascular responses (Fig. 2).

In order to detect possible differences between extreme levels of physical activity we compared BP values of the first (46 children) versus the fourth (43 children) subgroup. No difference between rest and adrenergic stimulation was observed other than an increased HR in the 4th level, as already shown by the analysis of the whole population.

Fig. 2. Systolic and diastolic blood pressure (top) and heart rate (bottom) in sedentary (hatched bars and closed circles) and physically active (open bars and open circles) 11-year-old children during isometric exercise and in the following recovery phase (total sample in the middle; male group on the left; female group on the right).
Twenty-four-hour urinary catecholamine excretion values were also not different in the 2 groups, both male and female (total: 27.0±15 vs 29.0±15 mcg/24 hr; males: 24.0±15 vs 28.3±15; females: 29.6±15 vs 34.9±15).

**Discussion**

The results of this study provide evidence that children of both sexes with a reported low level of physical activity have similar or only slightly higher resting BP and HR in comparison to children more frequently practicing sports. Moreover cardiovascular responses to tests stimulating the adrenergic nervous system were similar. Physical activity of the children was estimated by a modified Saltin questionnaire, originally planned to evaluate the leisure time physical activity of old former and still active athletes; this questionnaire had the advantage of being easily completed by the children, with the help of the investigators. The results of the questionnaire indicated that no more than 60% of the boys and 38% of the girls used to spend their leisure time practicing sports.

The cardiovascular response to sympathetic activity was evaluated by two different well reproducible tests:

1) mental arithmetic, which is a submaximal stress particularly dealing with the central nervous control of BP. It is also correlated to BP measurements during stressful situations, as shown by 24-hr BP monitoring.

2) isometric exercise by handgrip, which mainly measures the reflex increase in sympathetic activity and end-organ response. Initially this test requires a submaximal voluntary contraction, but its maintenance becomes increasingly difficult with time and leads to a maximal contraction, producing an ever-increasing vasomotor response. The reflex increase in the resistance of small arteries results in an excessive elevation of BP.

Under these two conditions a marked increase in BP and HR was detected in both the sedentary and the physically active groups. Since there was the possibility that the more advanced sexual maturation in females, who were more numerous in the sedentary group, might have influenced the outcome of the cardiovascular tests, a separate analysis by sex was also made and again the magnitude of the response was roughly similar in the 2 groups. Exaggerated cardiovascular responses to these tests have been found in children and adolescents with a family history of arterial hypertension, supporting the hypothesis that normotensive children at risk of developing arterial hypertension already have at this age an impairment of the adrenergic regulation and that altered BP responses to exercise might be useful in predicting future hypertension.
The relationship between physical activity and resting BP in children or young adolescents has also been evaluated. In particular, it was found that a decreased fitness is frequently associated with overweight and increased BP levels at rest. An inverse association between physical fitness, evaluated by HR response to a modified Harvard step test, and BP at rest have been found in two different studies.

The results of our study suggest that normotensive young adolescents with a sedentary life style have BP and HR levels at rest and during sympathetic stimulation only slightly higher than physically active children of the same age, independently of sex, body weight and family history for arterial hypertension. Whether BP and HR reactivity under physical exercise in children, as in adults, has predictive value for the development of hypertension is still under investigation. Two clinical studies have recently described the beneficial effects of regular physical training, through a decrease in the adrenergic tone, on BP of hypertensive adolescents and of healthy normotensive subjects. On the basis of our findings, however, it is not possible to add further support to the view of a favorable influence of physical activity on BP regulation. It must be remarked, however, that our population sample was represented by very young subjects, in whom differences in cardiovascular response to sympathetic stimulation might not yet be well established.

REFERENCES


