Introduction

Cardiovascular (CV) disease, a major cause of morbidity, mortality and healthcare costs among adults, is a progressive disease that has its roots in the early years of life. Focusing on puberty is essential, since it is an era of unique biological changes in human body, including changes in the CV system. Furthermore, adolescents rather than adults adopt independent behavior patterns that influence lifetime CV risk.

Nowadays, elevated blood pressure (BP) during childhood and adolescence is not so rare and increases the risk of hypertension in adulthood. Physical activity (PA) is considered a key component for the prevention and treatment of hypertension in children and adolescents. Thus, the purpose of our study was to assess the level of PA in Greek adolescents and its relation to BP levels. Methods: The study included 496 students aged 12–17 years who were enrolled on a volunteer basis. All children were subjected to BP measurement on two different occasions during a routine school day. Demographic, socio-economic and lifestyle characteristics were assessed by means of a standard questionnaire. Information on the frequency and duration of PA and on the amount of time spent on sedentary activities was obtained by the short-form self-administered questionnaire International Physical Activity Questionnaire-IPAQ. Results: The study population was divided in three groups according to the score achieved in IPAQ questionnaire: low PA (n = 39), moderate PA (n = 230) and high PA (n = 231). Children with high PA compared to those with low PA exhibited higher systolic BP and pulse pressure levels, greater prevalence of prehypertension/hypertension status, while heart rate was significantly lower as the level of PA rose (P < 0.05 for all cases). Intense PA was positively correlated to systolic BP (r = 0.139, P = 0.003) and pulse pressure (r = 0.22, P = 0.0001). Conclusion: Intense PA is associated with higher systolic BP, pulse pressure levels and lower heart rate in healthy young adolescents. PA should be practiced at a moderate intensity level in everyday life.

Keywords: adolescents, blood pressure, heart rate, physical activity

Relation between physical activity and blood pressure levels in young Greek adolescents: The Leontio Lyceum Study

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Nowadays, elevated blood pressure (BP) during childhood and adolescence is not so rare and increases the risk of hypertension in adulthood, contributing to the adverse CV outcome. In adults, hypertension is associated with a number of other markers of CV risk such as obesity, unhealthy nutrition pattern and physical inactivity.

Regular physical activity (PA), fitness and exercise are critically important for the health and well-being of people of all ages. Prospective studies have demonstrated that moderate-to-vigorous intensity PA at baseline seems to be associated with a lower incidence of hypertension among white men, regardless of body size. Further, interventional studies have demonstrated that increased PA reduces BP in hypertensive and normotensive individuals independently from weight loss. In light of these, PA should be practiced at a moderate intensity level in order to reduce systolic and diastolic BP. Thus, PA should be considered as an important measure for the prevention and treatment of hypertension in adulthood.

Even though for adults the effect of PA on BP is well established, the literature data are still limited regarding young adolescents. PA is a key component of the therapeutic lifestyle changes recommended for preventing and treating hypertension in children and in youth. The American Heart Association recommends that children and youth should participate in at least 60 min of moderate-to-vigorous PA daily for CV health promotion.

Since PA health behaviors track into adulthood, it is important to review the evidence-based findings in school and community settings for designing and implementing effective policy and programs to promote PA in young people. Thus, the purpose of the present cross-sectional study was to assess the level of PA in Greek adolescents and its relation to BP levels.

Methods

Study population

The Leontio Lyceum Study is an epidemiological cross-sectional survey, which was designed and conducted by the
Hypertension Unit of the 1st Cardiology Clinic of the Athens University, Hippokration Hospital from 2008 to 2009. The study, including data collection, has been designed according to the principles of the declaration of Helsinki (1989). The protocol of the study has been approved by the Education Institute of the Hellenic Ministry of Education as well as the ethics committee of our institution.

During April 2009, 650 students from Leontio Lyceum, aged 12–17 years (7th to 12th grade), were asked to participate in the study. The adolescents were enrolled on a voluntary basis. Prior to acceptance, children’s parents or guardians were fully informed about the objectives and methods of the study and did not provide written consent. Students receiving medical agents for any reason \( (n = 2) \), those with known diabetes mellitus \( (n = 1) \), hypothyroidism \( (n = 2) \) and chronic glomerulonephritis \( (n = 2) \) were excluded.

The final cohort included 496 students (response rate almost 80%). All participants were interviewed and evaluated by trained personnel (cardiologists, doctors of internal medicine, pediatricians and general practitioners). The number of enrolled children was adequate (statistical power: 80%) to evaluate two-sided hypotheses regarding standardized differences between various balanced groups (such as obese vs. non-obese children, physically active vs. inactive, etc.) >0.5 at the probability level of <0.05.

**BP measurement**

Office BP was measured by trained physicians on two different occasions during a routine school day. The first measurement was obtained at the end of the interview after replying to the study questionnaire and the second one at the end of the study protocol. Measurements were taken using validated oscillometric devices (Omron 705 IT; Omron Healthcare Europe BV, Hooftdorp, The Netherlands) with the patient in the sitting position after a 5 min rest. Three consecutive measurements of BP and heart rate were taken at heart level on each arm (a total of 12 measurements for every student) in each of the two sessions of BP measurements, as previously described. For each student, after calculating the mean BP value and the respective standard deviation for each adolescent separately, we excluded those values exceeding mean BP value ± two standard deviations. Consequently, the average of the remaining measurements was computed for each occasion separately (BP1 and BP2, respectively), as well as the average of BP1 and BP2. According to 2004 guidelines of the US National Heart, Lung, and Blood Institute (NHBLI) for hypertension in children and adolescents, hypertensives were considered those students who had BP >95th percentile for gender, age and height on both occasions (BP1 and BP2). In addition, prehypertensives were those students with BP >90th percentile on at least one occasion, and normal BP was defined as BP <90th percentile on both occasions.

**Anthropometric measurements**

In each subject, weight, height and waist-to-hip ratio were measured, while body mass index was also calculated. Waist circumference was measured at the midpoint between the bottom of the rib cage and above the top of the iliac crest from patients at minimal respiration to the nearest 0.1 cm.

**Demographic, socio-economic and lifestyle characteristics**

Using a questionnaire, developed for the purposes of the study, we retrieved information about age, sex, number of siblings, several indicators of family’s socioeconomic status (i.e. the existence of separate bedroom for each child o family) and several adolescents’ lifestyle characteristics, such as their smoking habits (i.e. if they were current smokers and how many cigarettes smoked per day), time spent on sedentary activities (i.e. watching television, working on a computer, playing video games and studying), the frequency and duration of adolescents’ PAs (brisk walking, swimming, etc.) as well as information on hospitalizations of the children. The socio-economic status indicators have been extensively used as indices of family’s economic status in developed societies.

**PA assessment**

Information on the frequency and duration of PA (brisk walking, swimming, etc.) and on the amount of time spent on sedentary activities (watching television, working on a computer and playing video games) was retrieved from the study’s questionnaire.

The International Physical Activity Questionnaire-IPAQ was proposed by the International Group for Consensus of Physical Activity Measurements under the seal of the World Health Organization. It deals about an instrument developed with the objective of estimating the habitual practice of PA of population of different countries and socio-cultural contexts.

Two IPAQ versions are available: a long and a short version. Both versions present self-administered or interview characteristics and search to provide information with regard to the walk frequency and duration, and daily activities that require physical efforts of moderate-high intensities, besides the time spent with activities performed in sitting position during days from the middle of the week (between Monday to Friday) and weekend (Saturday and Sunday), where a typical week or at least a week was considered as the reference period.

The short-form self-administered questionnaire was selected because this version is the most frequently suggested for the use in young populations. This version is composed of seven open questions and its information allows estimating the weekly time spent with different PA dimensions (walks and physical efforts of moderate-high intensities) and spent with physical inactivity (sitting position). Particularly, intensity was graded in qualitative terms such as light (expended calories <4 Kcal/min, i.e. walking slowly, cycling stationary, light stretching etc.), moderate (expended calories 4–7 Kcal/min, i.e. walking briskly, cycling outdoor, swimming moderate effort, etc.) and high (expended calories >7 Kcal/min, i.e. walking briskly uphill, long distance running, cycling fast or racing, swimming fast crawl, etc.).

All the participants were gathered in groups of five in a classroom. They received the short questionnaire with filling instructions, while no time limit was given for the task. Possible doubts were explained by the professionals in charge for the data collection. In addition, during the task, participants were not allowed to talk to each other in order to avoid possible undesirable interferences in their responses.

With that information, the time spent by each subject in the different PA categories was assessed. Thus, reported PA was classified as low (category 1) when no activity was reported or some activity was reported but not enough to meet the categories 2 and 3, as moderate (category 2) when either one of the following three criteria were fulfilled: 3 or more days of vigorous activity of at least 20 min per day, 5 or more days of moderate-intensity activity and/or walking of at least 30 min per day, 5 or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum of at least 600 metabolic equivalents (METs)-minutes/week and finally as high when one of the following two criteria were fulfilled: vigorous-intensity activity on at least...
Table 1 Baseline characteristics of the study population

<table>
<thead>
<tr>
<th></th>
<th>Low PA</th>
<th>Moderate PA</th>
<th>High PA</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>14.65 ± 1.71</td>
<td>14.13 ± 1.69</td>
<td>13.99 ± 1.52</td>
<td>0.07</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.64 ± 0.08</td>
<td>1.65 ± 0.09</td>
<td>1.66 ± 0.10</td>
<td>0.19</td>
</tr>
<tr>
<td>Weight (Kgr)</td>
<td>61.13 ± 12.26</td>
<td>60.24 ± 13.56</td>
<td>61.08 ± 13.8</td>
<td>0.78</td>
</tr>
<tr>
<td>Waist/hip ratio</td>
<td>0.82 ± 0.05</td>
<td>0.82 ± 0.05</td>
<td>0.82 ± 0.05</td>
<td>0.53</td>
</tr>
<tr>
<td>Body mass index (Kg/m²)</td>
<td>22.44 ± 3.29</td>
<td>21.87 ± 3.66</td>
<td>21.79 ± 3.36</td>
<td>0.35</td>
</tr>
<tr>
<td>Positive family history for hypertension</td>
<td>945 55</td>
<td>55</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>112.7 ± 9.7</td>
<td>116.0 ± 10.9</td>
<td>117.6 ± 11.6</td>
<td>0.035</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>66.49 ± 21.61</td>
<td>67.88 ± 7.17</td>
<td>66.64 ± 6.70</td>
<td>0.12</td>
</tr>
<tr>
<td>Pulse pressure (mmHg)</td>
<td>46.27 ± 8.07</td>
<td>48.15 ± 7.72</td>
<td>51.02 ± 9.21</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>88.7 ± 13.9</td>
<td>85.3 ± 11.5</td>
<td>82.3 ± 11.6</td>
<td>0.002</td>
</tr>
<tr>
<td>Prehypertension/hypertension (%)</td>
<td>5.7 15.2</td>
<td>20.3</td>
<td>0.15</td>
<td></td>
</tr>
</tbody>
</table>

PA, physical activity; BP, blood pressure.

Table 2 Physical activity continuous score and other activities reported by the study population

<table>
<thead>
<tr>
<th></th>
<th>Low PA</th>
<th>Moderate PA</th>
<th>High PA</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours of studying</td>
<td>3.15 ± 1.28</td>
<td>3.07 ± 1.30</td>
<td>2.77 ± 1.14</td>
<td>0.019</td>
</tr>
<tr>
<td>Hours of TV</td>
<td>1.85 ± 1.20</td>
<td>1.94 ± 1.09</td>
<td>1.82 ± 1.05</td>
<td>0.49</td>
</tr>
<tr>
<td>Hours of sports</td>
<td>0.94 ± 0.97</td>
<td>3.72 ± 1.90</td>
<td>8.80 ± 4.78</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hours of hobbies</td>
<td>3.59 ± 4.00</td>
<td>3.15 ± 3.32</td>
<td>4.37 ± 4.31</td>
<td>0.003</td>
</tr>
<tr>
<td>Leisure time</td>
<td>5.44 ± 3.96</td>
<td>5.09 ± 3.56</td>
<td>6.19 ± 4.39</td>
<td>0.012</td>
</tr>
<tr>
<td>METs walk</td>
<td>188.7 ± 158.9</td>
<td>365.3 ± 320.1</td>
<td>523.6 ± 481.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>METs moderate</td>
<td>148.8 ± 158.4</td>
<td>483.3 ± 415.0</td>
<td>529.8 ± 513.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>METs vigorous</td>
<td>35.2 ± 107.7</td>
<td>709.3 ± 544.0</td>
<td>3276.5 ± 2333.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>METs</td>
<td>372.8 ± 180.1</td>
<td>1558.1 ± 589.8</td>
<td>4330.0 ± 2306.6</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

PA, physical activity; TV, television; METs, metabolic equivalents.

Statistical analysis

Statistical analysis was performed by the SPSS (version 16.0 Chicago IL). Values were expressed as means or as percentages. Means were compared by the Student’s t-test for independent samples. Analysis of categorical data was carried out with the chi² test, or Fischer’s exact test when appropriate. Differences between the three groups of different levels of PA were compared by analysis of variance (ANOVA), and the Scheffe post hoc test was used to locate the pairwise differences. Pearson correlations were calculated to examine univariate relation of PA parameters to continue variables. The limit of statistical significance was set at P < 0.05.

Results

Overall, the study population was divided in three groups according to the categorical score achieved in IPAQ questionnaire: low PA (n = 39), moderate PA (n = 230) and high PA (n = 231). Assessing the differences within the three groups, a significant higher level of systolic BP (P = 0.035) and pulse pressure (P < 0.001) was observed in subjects of high PA compared to those with low PA, while heart rate was significantly lower as the level of PA rose (P = 0.002) (table 1). Moreover, children with high PA exhibited a greater prevalence of prehypertension/hypertension compared to those with low PA (20.3% vs. 5.7%, P = 0.045). No difference was observed between the three groups with respect to body mass index and waist-to-hip ratio.

Exploring the differences observed within groups, considering PA and the participation in other activities, it was noticed, as expected, that as the level of PA rose so did the METs (P < 0.0001). Furthermore, subjects of high PA spent significantly less time in studying (P = 0.019) and more time in hobbies (P = 0.003) in comparison to those of moderate and low PA levels (table 2).

When comparing gender differences between low and moderate PA, no significant difference was seen (P = 0.14), while between low and high PA, a significant difference was observed in the participation to vigorous activities in favor of males (P > 0.001).

Univariate analysis revealed a positive correlation of METs vigorous to systolic BP (r = 0.139, P = 0.003), to pulse pressure (r = 0.22, P < 0.001), to the hours spent for hobbies (r = 0.114, P = 0.014) and leisure time (r = 0.095, P = 0.04) and a negative correlation to gender (r = −0.172, P = 0.0001), heart rate (r = −0.176, P < 0.001) and hours of study (r = −0.15, P = 0.001). Moderate METs revealed no such correlations, while walk METs revealed a positive correlation with age (r = 0.202, P = 0.001), pulse pressure (r = 0.09, P = 0.034), hours spent for hobbies (r = 0.79, P < 0.001) and leisure time (r = 0.187, P < 0.001). Finally, METs total presented with a positive correlation with systolic BP, pulse pressure [(r = 0.15, P = 0.001), (r = 0.235, P < 0.001), respectively], hours spent for hobbies and leisure time [(r = −0.172, P = 0.001), (r = −0.170, P < 0.001), (r = −0.135, P = 0.004), respectively] (figure 1).

Discussion

The main finding of the present study is that in Greek adolescents, and especially males, vigorous exercise is associated with higher systolic BP and pulse pressure levels than low and moderate exercise. A dose–response relationship exists between levels of PA, systolic BP and pulse pressure also
arterial compliance with potential adverse consequences. In exercise pressor reflex-induced alterations in BP. Systolic BP rises fairly linearly with increases in exercise intensity. PA may play an important role in the prevention of hypertension; however, the dose–response relation between PA and BP in the adolescent age group remains debatable. There are two main approaches, that is, the attained BP increases as the muscle contraction is maintained. Isometric exercise, typical in sports, such as weight lifting, wrestling, football blocking or rugby, does not lead to changes in muscle length. Systolic BP increases in direct proportion to the effort exerted by one or more muscle groups rather than the actual muscle mass involved. Systolic BP increases as the muscle contraction is maintained.

Another possible explanation for the elevated systolic BP observed in these subjects undergoing vigorous activities is the phenomenon of spurious systolic hypertension. Spurious systolic hypertension, first described by O'Rourke, in a small number of asymptomatic apparently healthy young men with exaggerated amplification of the arterial pressure wave traveling to the periphery. Thus, these subjects may erroneously be considered as hypertensives, since they do not present impaired vessel function, but particularly elastic arteries in the periphery.

Moreover, in the present study, young subjects with intense exercise habits present with lower heart rate in comparison to those trained low and moderately. Cross-sectional differences between athletes and controls support the notion of increased parasympathetic and/or decreased sympathetic drive in endurance-trained individuals. Specifically, the resting bradycardia observed in endurance-trained athletes is commonly accompanied by augmented markers of cardiac vagal modulation. However, longitudinal data are less consistent, and a recent review suggested that further studies should be carried out to clarify the effect of exercise on heart rate. Thus, the present study attributes to the previously reported observation that there is a clear reduction in heart-rate levels with the increase in exercise intensity, as also applied by the use of METs as a quantitative measurement of PA.

Another point of the present study was that young adolescents with moderate-to-vigorous activity had more leisure time, and time for hobbies spent rather than studying. Thus, the participation in intensive exercise alters not only hemodynamic parameters in this age, but also the whole living profile of teenagers. Furthermore, leisure time and time spent in hobbies were positively associated with BP levels and body size, in agreement with previous studies. Notably, boys are more active than girls and spend more time in vigorous PA and less time in sedentary activities. The results of comprehensive meta-analyses suggest that socio-cultural factors rather than...
biological differences are primarily responsible for the differences between boys and girls in PA. Hence, these results may possibly be explained by social differences found in childhood and adolescence of both sexes.\textsuperscript{16}

The present study has some limitations. First, its cross-sectional and observational nature prevents us from making causal inferences about the relation between PA and BP. Although objective in nature, the IPAQ questionnaire presents self-reported level of PA. However, it can provide useful baseline data of PA and could be repeated to ascertain population trends. Moreover, obesity was assessed indirectly by measuring body mass index, not being able to capture variations in fat and fat-free mass. Finally, although a proportion of subjects denied participation in the study, the number of enrolled children was adequate to evaluate two-sided hypotheses.

The strengths of this study include the use of a large and representative study sample, the use of an objective PA measure and the statistical modeling approach that allowed us to accurately characterize the dose–response relation between PA and BP. In conclusion, vigorous activity was associated with higher BP levels, lower heart rate and prevalence of prehypertension/hypertension status, pointing to a possible detrimental effect of intensive exercise on youths’ health, while leisure time was positively associated with BP and body mass index. PA should be practiced at a moderate intensity level in everyday life in order to avoid increased BP levels.

Acknowledgements

We thank the Greek Ministry of Education, the Hellenic Society of Cardiology and all the teachers who readily consented to carry out the study during school hours, as well as to all the participated children and their parents.

Conflicts of interest: None declared.

Key points

- Elevated BP during childhood and adolescence increases the risk of hypertension in adulthood. PA is a key component of the therapeutic lifestyle changes recommended for the prevention and treatment of hypertension in children and adolescents, but it is known how different levels of PA is related to BP levels.
- Information on the frequency and duration of PA and on the amount of time spent on sedentary activities was obtained by the short-form self-administered questionnaire International Physical Activity Questionnaire-IPAQ in 496 students aged 12–17 years.
- A significant higher level of systolic BP and pulse pressure, as well as greater prevalence of prehypertension/hypertension status was observed in children of high PA, while heart rate was significantly lower as the level of PA rose.
- PA should be practiced at a moderate intensity level in everyday life in order to avoid increased BP levels.

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