PHYSICAL ACTIVITY, CARDIORESPIRATORY FITNESS, AND THE METABOLIC SYNDROME IN ADOLESCENTS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: There is a substantial body of evidence that in adults, physical inactivity or low cardiorespiratory fitness levels are strongly associated with the development of metabolic syndrome. Although this association has been studied extensively in adults, little is known adolescents. The aim of this study was to analyze the association between physical activity and cardiorespiratory fitness levels with the metabolic syndrome in Brazilian adolescents.

Methods: A random sample of 223 girls (mean age, 14.4±1.6 years) and 233 boys (mean age, 14.6±1.6 years) was selected for the study. Physical activity level was determined by Bouchard Three-day physical activity record. Cardiorespiratory fitness was estimated by the Leger 20-meter shuttle run test. The metabolic syndrome components assessed included waist circumference, blood pressure, HDL-cholesterol, triglycerides, and fasting plasma glucose. Independent Student t-tests were utilized to compare the genders groups, and the association between physical activity and VO$_{2\text{máx}}$ and the presence of metabolic syndrome was calculate using logistic regression models adjusted for age and sex.

Results: A high prevalence of the metabolic syndrome was observed in sedentary adolescents (males, 9%; females, 7.2%) and adolescents with low cardiorespiratory fitness levels (males, 13.9%; females, 8.6%). Significant relationships were found between metabolic syndrome with low cardiorespiratory fitness levels (OR: 3.0 [1.13-7.94]).

Conclusion: The prevalence of metabolic syndrome is high among adolescents who are sedentary and those with low fitness levels. Prevention strategies for the metabolic syndrome should concentrate on enhancing fitness levels early in life.
**Background**

The term metabolic syndrome (MetS) refers to a clustering of cardiovascular risk factors represented by high blood pressure, overweight / obesity, hypertriglyceridemia, low high density lipoprotein-cholesterol (HDL-C), and glucose intolerance. The diagnosis of MetS in adults and recently in children and adolescents is established when three or more of the five individual elements exist together in the same subject\(^1,2\).

In adults, the MetS is associated with a greatly elevated risk of coronary heart disease\(^3\) and diabetes mellitus\(^4\), while in children and adolescents there is a direct relationship between the number of cardiovascular risk factors present and the severity of asymptomatic atherosclerosis\(^5\).

Therefore, the interest in the role of lifestyle in the development of MetS has increased. There is a substantial body of evidence that in adults, physical inactivity or low cardiorespiratory fitness levels are strongly associated with the development of MetS\(^6-8\). Although this association has been studied extensively in adults, little is known about MetS in youths.

Evidence also suggests that sedentary behavior, low levels of physical activity, and cardiorespiratory fitness in youth track into adulthood\(^9\), likewise metabolic risk factors also appear to track over time\(^10\), and this may predispose young people to disease in later in life\(^11\).

Based on this information, the aim of this study was to estimate the prevalence of MetS and to analise the association between physical activity and cardiorespiratory fitness levels with MetS in a random sample of Brazilian adolescents.
Methods

Sample

This cross-sectional study was carried out in the city of Curitiba, Paraná, Brazil. A stratified random sample of 456 adolescents (223 girls [49%] and 233 boys [51%]) were evaluated. The sample size consisted of school children registered in the public education system. The city of Curitiba has a population of 1,678,965 inhabitants with a human development index by 0.763. Data collection from 7 schools took place between April and November 2009 and the schools were randomized according to type (age range and gender), location (urban, suburban, and rural), and the socioeconomic characteristics.

All participants completed a physical activity questionnaire. Height, weight, blood pressure, cardiorespiratory fitness, and lipid profiles were measured in all subjects. Only students between 10 and 18 years of age were included in the analysis. Exclusion criteria were the known presence of diabetes and the use of medications that alters blood pressure, glucose, or lipid metabolism.

Written informed consent was obtained from the adolescent’s parent or legal guardian after they were given a detailed written explanation of the aims of the study, and the possible hazards, discomfort, and inconvenience. All participants were given the option to drop-out at any time without consequence. This research was approved by the Ethics Committee of the Federal University of Paraná (Resolution 196/96). All procedures and methods in this study conformed to the ethical guidelines laid down in the World Medical Association’s Declaration of Helsinki and its subsequent revisions.

Measurements

Physical activity was estimated from a self-report. The Bouchard\textsuperscript{12} Three-Day Physical Activity Record was used during two days of the week (Monday and Tuesday) and one weekend day (Sunday). The daily activities were recorded by adolescents in 15 minute segments throughout the day, on a physical activity scale of 1-9 (1 being sedentary active, and 9 being very active). The time spent in exercises with moderate to vigorous intensity ($\geq$ 3 METs) was
added and then used to determinate the total modetare to vigorous physical activity (MVPA) expressed in minutes for day. The mean value from the three days was considered for the analysis.

The reproducibility of this instrument was \( r = 0.91 \) in subjects from 10 years old\(^1\), and was validated for use in adolescents using the technique of doubly labeled water\(^2\).

Blood samples were taken by trained and certified nurses between 8:00 and 9:00 AM following an overnight fast. After the blood samples had been drawn, the participants were served breakfast and then continued with the physical and fitness measurements. The samples were immediately centrifuged and the serum or plasma separated and placed on dry ice for shipment back to the chemistry laboratory. A single certified laboratory was used for all analyses. HDL-C, triglycerides, and glucose were analyzed by colorimetric assay on a random-access Spectrum CCX analyzer (Abbott Diagnostics, Abbott Park, IL, USA). All the measurements were realized in the morning, in the same day and in the same sequence.

The data used for this study were collected at each scholl site. Physical measurements were taken by trained research assistants after blood analyses. Body height was measured without shoes to the nearest 0.1 cm with a transportable stadiometer. Body weight was measured in light clothing to the nearest 0.1 kg with a calibrated beam balance scale. Waist circumference was measured at the end of gentle expiration, midway between the lower rib margin and the iliac crest.

Aerobic fitness was estimated using the 20-meter shuttle run test as described by Leger et al.\(^4\). The test was realized in a gym with plane surface. \( \text{VO}_{2\text{máx}} \) in ml.kg\(^{-1}\)min\(^{-1}\) was calculated according to the equation validated by Léger et al.\(^10\) as follows: \( \text{VO}_{2\text{máx}} = 31.025 + 3.238 \times \text{velocity} - 3.248 \times \text{age} + 0.1536 \times \text{velocity} \times \text{age} \). These authors reported a relationship to directly measured \( \text{VO}_{2\text{máx}} \) of 0.84 and a test–retest correlation of 0.98.

Resting blood pressure (BP) was performed by trained technicians following the parameters established for The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and
Adolescents\textsuperscript{15}. The students were asked to rest in the sitting position for 5–10 min prior to assessment of BP. The cuff was pumped to 180–200 mmHg. Thereafter, the pressure was lowered by 1–3 mmHg/second. The systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured in the right arm using a sphygmomanometer of mercury column. The SBP was defined as Korotkoff sound phase 1 and the DBP as the Korotkoff sound phase 5 or when the sound disappeared.

**MetS definitions**

To allow comparisons between studies, we used the age-modified standards of the ATP III MetS criteria published previously\textsuperscript{16} and utilized in others researches\textsuperscript{17,18}. Abdominal obesity was considered as waist circumference $\geq 90^{th}$ for age and gender\textsuperscript{19}. Hypertension was considered as having an average SBP or DBP $> 90^{th}$ by age and gender based on published reference data\textsuperscript{15}. Adolescents were considered to have excessive total triglyceride levels if blood concentrations were $\geq 110$ mg/dL. HDL-C levels were considered low at a level of $\leq 40$ mg/dL, while fasting blood glucose levels $\geq 110$ mg/dL were considered indicative of hyperglycemia, as used previously\textsuperscript{16}. MetS was diagnosed when three or more of the five individual elements were found together in the same individual.

**Statistical procedures**

The descriptive data are shown as the mean and standard deviation. The Kolmogorov Smirnov test was used to verify the normality of the physical activity and physical fitness distribution data. Independent Student $t$-tests were utilized to compare the genders groups. The prevalence of MetS and its components was calculated with regard to different physical activity and cardiorespiratory fitness categories. Since there are no prescribe thresholds for aerobic fitness, the lowest and highest tertiles of these two variables were used in the analyses. For physical activity, the thresholds were: sedentary $< 60$ min.day of MVPA; active: $\geq 60$ and $< 90$ min.day of MVPA; very active: $\geq 90$ min.day of MVPA.
The association between physical activity and VO$_{2\text{máx}}$ and the presence of MetS was calculated using logistic regression models adjusted for age and sex. The outcome variable was the presence or absence of the MetS. The exposure variables were: meet or not the recommendations of 60 min.day of MVPA participation; VO$_{2\text{máx}}$ tertiles expressed per kilogram of body weight (ml.kg$^{-1}$min$^{-1}$). The statistical analyses were performed using SPSS, version 13.0 for Windows (Chicago, IL, USA)$^{20}$, with a significance level stipulated at p<0.05.

**Results**

Table 1 presents descriptive data for the parameters evaluated in both genders by sex. Apart from height, weight, VO$_{2\text{máx}}$, SBP, and glucose, which were higher for the males, no other parameters differed by genders.

The prevalence of MetS was 7.7% among Brazilian adolescents. MetS was more common in males (10.2%) than females (5%). The proportion of subjects who had one or more individual risk factors was 77.1%.

When examined by physical activity and cardiorespiratory fitness levels (Figures 1 and 2), the increased prevalence of MetS was observed in the sedentary adolescents and with low fitness levels.

The prevalence of MetS increased significantly with reduction in physical activity and cardiorespiratory fitness levels. The males showed higher prevalences of MetS than females in all levels of physical activity and fitness.

Significantly higher ratios (p<0.05) were found for high and low VO$_{2\text{máx}}$ (table 2). No significant relationships were observed between the MetS with physical activity levels.

**Discussion**

Cardiovascular disease risk factors in children and adolescents have been assessed in many studies, however, most studies have looked at a single risk factor or a combination of risk factors$^{21-24}$. In this study, we investigated the association between MetS with physical activity and fitness in a random sample of Brazilian adolescents and a significant relationship was found for the male gender.
Diverse definitions of pediatric MetS have been used in various populations\textsuperscript{16,25,26}. Our data showed that the prevalence of the MetS in Brazilian adolescents (7.7\%) is consistent with previous published results. Data from these studies suggest that the prevalence of MetS varies between 3 and 12\% in representative sample of youth\textsuperscript{16-18,27}. However, there are not others studies pertaining to the prevalence of the MetS in Brazilian children and adolescents with which to compare.

Considering the prevalence of MetS by physical activity and cardiorespiratory fitness levels, the results of the present study suggest that adolescents with higher physical activity levels and higher VO\textsubscript{2\text{max}} had less MetS.

Andersen et al.\textsuperscript{28} related lower VO\textsubscript{2\text{max}} in adolescents with three or more risk factors. Ribeiro et al.\textsuperscript{22} (2004) showed that children and adolescents with high physical activity level have a lower number of biological risk factors for coronary disease.

While the level of each individual risk factor may be influenced by many factors, including genetics and lifestyle, an aggregation of risk factors may indicate a common underlying causative factor\textsuperscript{3}. Pediatric researchers have investigated individual metabolic abnormalities that increase cardiovascular risk\textsuperscript{29-31}.

McMurray et al.\textsuperscript{32} found high incidence of MetS in adolescents with history of low fitness and physical activity levels. Indeed, lifestyle factors, such as physical activity and cardiorespiratory fitness, may influence the development of MetS\textsuperscript{28}.

However, researches suggest that physical activity and cardiorespiratory fitness influence metabolic risk trough separate pathways or that cardiorespiratory fitness is a marker for specific muscle characteristics, for example, muscle fiber-type composition, which may affect metabolic health. Indeed, insulin-stimulated glucose transport\textsuperscript{33} and expression of the insulin-regulated glucose transporter GLUT4 maybe muscle fiber specific, and others have suggested that slow-twitch muscle fiber are associated with increased lipid oxidation\textsuperscript{34}. 
An important distinction between physical activity and cardiorespiratory fitness is the intraindividual day-to-day variability; physical activity will undoubtedly vary on a daily basis, whereas cardiorespiratory fitness will remain relatively static, taking time to change. This variability will impact on the ability to measure these two quantities and consequently will influence the ability to demonstrate their relationship with metabolic outcomes. \(^{35}\)

Future intervention studies should focus on the effect on cumulative risk because changes in single risk factors are modest even if the effect of the intervention might be important. Further, it has been difficult to argue for specific levels of physical activity or fitness in children and adolescents, which could indicate an unhealthy condition.

The primary limitation of this study was that MetS outcomes depend on our definition of MetS, a problem inherent to any extrapolation of the adult definition to a pediatric population and the lack of reference data for Brazilian pediatric population. Other limitation was the use of self-report instrument to measure physical activity, partly due to the intermittent nature of youth physical activity. However, the three day physical activity record has been considered a valid instrument for physical activity evaluation in population-based studies. \(^{13}\)

**Conclusion**

In summary, our results demonstrate that the prevalence of MetS is higher among Brazilian adolescents who are sedentary and have low cardiorespiratory fitness levels, and there was a significant relationship between MetS and cardiorespiratory fitness levels.

Thus, the development of MetS in adolescents should be avoided using strategies that concentrate on enhancing fitness and physical activity levels to prevent its consequences later in life.
Abbreviations

MetS: metabolic syndrome; HDL-C: high density lipoprotein-cholesterol; METs: metabolic equivalents; BP: blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; MVPA: moderate to vigorous physical activity; SD: standard deviation; OR: odds ratio; 95% CI: confidence interval of 95%.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

ASN was the principal researcher responsible for the collection, analysis and interpretation of data, as well as for drafting the manuscript. RDB, AZU, and LPGM was involved in analysis and interpretation of data and also in critical revision of the paper. MCSB, SGS, and WC were involved in revising the manuscript critically for important intellectual content.
References


Table 1. Characteristics of subjects for all studied parameters; values are the mean (SD)

<table>
<thead>
<tr>
<th></th>
<th>Males N = 233</th>
<th>Females N = 223</th>
<th>p</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Age (years)</td>
<td>14.6</td>
<td>1.6</td>
<td>14.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.1</td>
<td>11.6</td>
<td>158.8</td>
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<tr>
<td>Weight (kg)</td>
<td>57.1</td>
<td>12.5</td>
<td>51.7</td>
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<tr>
<td>Waist circumference (cm)</td>
<td>70.8</td>
<td>8.9</td>
<td>65.5</td>
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<tr>
<td>VO\textsubscript{2}máx (ml\textsuperscript{-1}kg\textsuperscript{-1}min\textsuperscript{-1})</td>
<td>49.0</td>
<td>6.2</td>
<td>40.5</td>
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<tr>
<td>MVPA</td>
<td>136.8</td>
<td>103.3</td>
<td>75.1</td>
</tr>
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<td>SBP (mmHg)</td>
<td>100.7</td>
<td>13.9</td>
<td>95.1</td>
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<tr>
<td>DBP (mmHg)</td>
<td>69.1</td>
<td>10.6</td>
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<td>HDL-C (mg/dL)</td>
<td>45.2</td>
<td>11.0</td>
<td>49.9</td>
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<td>Triglycerides (mg/dL)</td>
<td>89.3</td>
<td>41.3</td>
<td>85.1</td>
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<tr>
<td>Fasting glucose (mg/dL)</td>
<td>89.4</td>
<td>13.6</td>
<td>83.7</td>
</tr>
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</table>

Moderate-Vigorous Physical Activity (MVPA); Systolic blood pressure (SBP); Diastolic blood pressure (DBP).
Table 2. Odds ratio between MetS with physical fitness and physical activity levels adjusted for age and sex

<table>
<thead>
<tr>
<th>Metabolic Syndrome</th>
<th>OR</th>
<th>Confidence interval</th>
<th>p</th>
</tr>
</thead>
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<tr>
<td>High VO$_{2\text{max}}$ (3$^{\text{rd}}$ tertile)</td>
<td>1</td>
<td>---</td>
<td>---</td>
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<tr>
<td>Moderate VO$_{2\text{max}}$. (2$^{\text{nd}}$ tertile)</td>
<td>1.9</td>
<td>0.70</td>
<td>5.48</td>
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<tr>
<td>Low VO$_{2\text{max}}$. (1$^{\text{st}}$ tertile)</td>
<td>3.0</td>
<td>1.13</td>
<td>7.94</td>
</tr>
<tr>
<td>Active (≥ 60 min.day of MVPA)</td>
<td>1</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Sedentary (&lt; 60 min.day of MVPA)</td>
<td>1.25</td>
<td>0.60</td>
<td>2.60</td>
</tr>
</tbody>
</table>
Figure 1. Prevalence of MetS according to time participation in MVPA
Figure 2. Prevalence of MetS according to cardiorespiratory fitness levels