



# Cardiorespiratory Fitness and Blood Pressure: A Longitudinal Analysis

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**Objectives** To examine the association between cardiorespiratory fitness and cardiovascular indices 2 years later, and to determine whether changes in cardiorespiratory fitness are associated with cardiovascular indices at a 2-year follow-up in adolescents.

**Study design** The sample comprised 734 adolescents (349 girls) aged 12-18 years followed for 3 years from the LabMed Physical Activity Study. Cardiorespiratory fitness was assessed by the 20-meter shuttle run test. Height, weight, waist circumference, and resting blood pressure (BP) were measured according to standard procedures.

**Results** Regression analyses showed a significant inverse association between cardiorespiratory fitness at baseline and systolic BP ( $B = -0.126$ ;  $P = .047$ ) and rate pressure product ( $B = -29.94$ ;  $P = .016$ ), at follow-up after adjustments for age, sex, height, pubertal stage, socioeconomic status, and waist circumference. Significant differences were found between cardiorespiratory fitness groups (fit vs unfit) at baseline and systolic BP and rate pressure product at follow-up ( $P < .05$  for all). Analysis of covariance showed a significant association between cardiorespiratory fitness changes and systolic BP ( $P = .024$ ) and rate pressure product ( $P = .014$ ), after adjustment for age, sex, height, pubertal status, socioeconomic status, and waist circumference.

**Conclusions** Changes in cardiorespiratory fitness during adolescence were associated with cardiovascular indices over a 2-year period. Adolescents with persistently low levels of cardiorespiratory fitness exhibited the highest levels of systolic BP and rate pressure product. (*J Pediatr* 2018;192:130-5).

Globally, cardiovascular disease accounts for approximately 17 million deaths annually,<sup>1</sup> and hypertension is responsible for at least 45% of deaths due to heart disease each year.<sup>1</sup> The prevalence of elevated blood pressure (BP) in children and adolescents has become a significant public health issue.<sup>2</sup> BP seems to track from childhood to adulthood, and an elevated BP during childhood is likely to predict adult hypertension.<sup>3</sup> Hypertension appears to be one of the major modifiable risk factors for cardiovascular disease with roots in childhood,<sup>3,4</sup> and thus studies are needed to identify the determinants of BP tracking in childhood and adolescence.<sup>3</sup>

Findings from cross-sectional studies in adolescents have shown that low cardiorespiratory fitness is associated with increased BP.<sup>5,6</sup> In addition, longitudinal studies in adulthood have shown that a high level of fitness in childhood is associated with lower BP in adulthood.<sup>7,8</sup> Kvaavik et al<sup>9</sup> reported that physical fitness levels at age 13 years were inversely related to systolic and diastolic BP 2 years later.

The aims of this study were to examine the association between cardiorespiratory fitness and cardiovascular indices 2 years later, and to determine whether changes in cardiorespiratory fitness are associated with cardiovascular indices at a 2-year follow-up in a sample of adolescents.

## Methods

The present study is part of the Longitudinal Analysis of Biomarkers and Environmental Determinants of Physical Activity (LabMed Physical Activity Study), a school-based cohort study conducted in the northern region of Portugal to evaluate independent and combined associations of dietary intake and fitness levels with cardiometabolic risk factors. Detailed descriptions of the sampling and recruitment approaches and data collection and analysis strategies are available elsewhere.<sup>10,11</sup> In short, selection of schools was based on pragmatic, budgetary, and logistical reasons. Thus, a total of 5 schools were selected at random from the list of schools that had a previously established collaboration agreement with our research center and that met the foregoing criteria. Baseline data for 1229 adolescents aged 12-18 years were collected in 2011, and 1011 and 789 of these

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BP Blood pressure

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adolescents were reevaluated 1 and 2 years later, respectively. Of these subjects, 734 (349 girls) had complete data at baseline and the 2-year follow-up for the variables of interest and were included in the present study. None of the subjects was taking any medication or had any clinically manifest illness. The subjects were advised to abstain from alcohol and tobacco and to avoid exercise for a minimum of 24 hours before tests. Throughout the study period, no exclusion criteria were applied, to avoid discrimination. However, for the present analysis, only apparently healthy adolescents were considered.

The protocol was conducted according to the World Medical Association's Declaration of Helsinki for Human Studies. The Portuguese Data Protection Authority (1112434/2011), Portuguese Ministry of Science and Education (0246200001/2011), and Faculty of Sport, University of Porto approved the study. All participants were informed of the study's aims, and written informed consent was obtained from each participating adolescent and his or her parent or guardian.

Cardiorespiratory fitness was assessed with the 20-meter shuttle run test.<sup>12</sup> In this field-based test for evaluating cardiorespiratory fitness in children and youth, participants run back and forth between 2 lines set 20 meters apart.<sup>13</sup> Running speed starts at 8.5 km/hour and increases by 0.5 km/hour each minute, reaching 18.0 km/hour at the 20th minute. Each new level was announced on a tape player. The participants were instructed to keep up with the pace until exhausted. The test was finished when the participant failed to reach the end lines concurrent with the audio signals on 2 consecutive occasions. Otherwise, the test ended when the participant stopped because of fatigue. The participant received verbal encouragement from the investigator to achieve maximum performance, that is, to keep running as long as possible. The test was performed once, and the number of shuttles performed by the participant was recorded to calculate maximal oxygen consumption using the Léger equation.<sup>12</sup> Adolescents were also classified into 2 groups (fit and unfit) according to specific cutpoints for adolescents.<sup>14</sup>

BP was measured using a Dynamap vital signs monitor (model BP 8800; Critikon, Tampa, FL). An appropriately sized cuff was used for each participant.<sup>15</sup> Trained nurses took measurements, and all adolescents were required to sit and rest for at least 5 minutes before to the first BP measurement. Measurements were taken with the participants seated and relaxed with the feet resting flat on the floor. Two measurements were taken in the nondominant arm, after 5 and 10 minutes of rest and abstinence from coffee, tobacco, and alcohol. The mean of these 2 measurements was recorded. If the 2 measurements differed by  $\geq 10$  mmHg, a third measure was taken, and the first of these was discarded.<sup>16</sup> This approach was used in a previous study in a population with similar characteristics.<sup>17,18</sup> The rate pressure product was calculated as (heart rate  $\times$  systolic BP), and pulse pressure was defined as the difference between systolic BP and diastolic BP.

Socioeconomic status was assessed with the Family Affluence Scale,<sup>19</sup> developed specifically to measure children's and adolescents' socioeconomic status in the context of the Health Behaviour in School-Aged Children Study.

Body height was measured to the nearest 0.1 cm with the participant in bare or stocking feet standing upright against a portable stadiometer (Seca 213; Seca, Hamburg, Germany). Body weight was measured to the nearest 0.10 kg with the participant dressed in light clothing without shoes, using a portable electronic weight scale (Inner Scan BC532; Tanita, Tokyo, Japan).<sup>20</sup> Body mass index was calculated as the ratio of body weight (kg) to body height ( $m^2$ ), and the participants were classified according to the Cole body mass index categories.<sup>21</sup> Waist circumference measurements were made midway between the lower rib margin and the anterior superior iliac spine at the end of normal expiration following standard procedures.<sup>20</sup>

Self-assessment of pubertal stage was performed by having the participant choose the specific pictures for Tanner stages of sexual maturation that best described his or her current stage of development (breast and pubic hair development in girls and genital and pubic hair development in boys, ranging from stage I to V), according to the criteria of Tanner and Whitehouse.<sup>22,23</sup>

Descriptive data for participants' baseline characteristics are shown as mean  $\pm$  standard deviations. Paired *t* tests were used to evaluate differences between baseline and follow-up variables.

In multiple linear regression analyses, systolic and diastolic BP, pulse pressure, and rate pressure product at baseline and follow-up were entered as dependent variables in separate models; cardiorespiratory fitness at baseline was entered as an independent variable; and age, sex, height, pubertal stage, socioeconomic status, and waist circumference were included as covariates. These analyses controlled for the corresponding baseline value of the dependent variable. We also used ANCOVA to study differences in systolic and diastolic BP, pulse pressure, and rate pressure product at follow-up by cardiorespiratory fitness level at baseline (high vs low). Systolic and diastolic BP, pulse pressure, and rate pressure product at follow-up were entered as dependent variables in separate models; cardiorespiratory fitness (fit vs unfit) was entered as an independent variable; and age, sex, height, pubertal stage, socioeconomic status, and waist circumference at baseline were included as covariates. These analyses also controlled for the corresponding baseline value of the dependent variable.

To determine whether changes in cardiorespiratory fitness (from baseline to follow-up) are associated with cardiovascular indexes in adolescents at follow-up we computed a cardiorespiratory fitness variable as follows: adolescents who were in the unfit category at both baseline and follow-up were classified as "persistent low fitness," and those who dropped from the fit category at baseline to the unfit category at follow-up were classified as "decreasing fitness." The other categories were "persistent high fitness" (fit category at both baseline and follow-up), and "increasing fitness," those who changed from the unfit category at baseline to the fit category at follow-up. The association of cardiorespiratory fitness change (persistent low, decreasing, persistent high, and increasing) categories with cardiovascular indices at follow-up was assessed by ANCOVA. The cardiovascular indexes at follow-up were entered as dependent variables in separate models; cardiorespiratory fitness change category was entered as an independent variable; and

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