# Obesity as a Mediator between Cardiorespiratory Fitness and Blood Pressure in Preschoolers

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**Objectives** To analyze the relationships between body mass index (BMI), cardiorespiratory fitness (CRF), and blood pressure (BP), and to examine whether obesity acts as a mediator between fitness and BP in children.

**Study design** A cross-sectional analysis using a population-based sample of 1604 school children aged 4-7 years attending 21 schools from the provinces of Ciudad Real and Cuenca, Spain, was undertaken. Data on anthropometric variables, BP measurements, and CRF were collected. The relationships between body composition (BMI, percent body fat, and waist circumference), CRF, and mean arterial pressure was estimated using Pearson correlation coefficients. ANCOVA tested the differences in BP measurements by categories of BMI and CRF, controlling for different sets of confounders. The PROCESS macro developed by Preacher and Hayes was used for mediation analysis.

**Results** BP values were significantly higher in school children with excess weight and poorer CRF. In addition, BMI acts as a full mediator in the association between CRF and mean arterial pressure in boys at 62.28% ($z = -5.433$; $P \leq .001$) and a partial mediator in girls at 35.24% ($z = -5.246$; $P \leq .001$).

**Conclusions** BMI mediates the relationship between CRF and mean arterial pressure. These findings highlight the importance of maintaining a healthy weight for the prevention of high BP levels in childhood. *(J Pediatr 2017;182:114-9).*

**Trial registration** ClinicalTrials.gov: NCT01971840.

Hypertension is a chronic disease estimated to have a prevalence of between 3% and 5% in children.[1] Moreover, high levels of blood pressure (BP) in childhood are associated with a high risk of hypertension in adulthood.[1,2] Hypertension, excess weight, and adiposity in children and adolescents are associated with the risk of coronary heart disease and premature mortality in adulthood.[3]

According to the World Health Organization,[4] a growing prevalence of childhood obesity has been seen in recent decades. In 2013, 42 million children under the age of 5 years were estimated to be overweight. In Spain, the prevalence of children aged 4-7 years who are overweight, including obesity, is around 20%.[5]

Several studies have shown that the prevalence of hypertension increases progressively with increasing body mass index (BMI), with a strong association between the 2 variables.[1,6] Obesity is thus an important risk factor for increased BP in children. A consistent relationship has also been described between childhood obesity and the development of other cardiometabolic risk factors such as dyslipidemia and insulin resistance,[7,8] in addition to high BP, which are predictors of cardiovascular disease in adulthood.[8-11] Conversely, low levels of physical activity and cardiorespiratory fitness (CRF) have been related to worse levels of different cardiovascular risk factors in children, including hypertension.[12,13] It is known that there is a negative relationship between obesity and CRF, so that CRF decreases with increasing obesity.[14] It has also been reported that obesity acts as a mediating variable in the relationship between CRF and cardiometabolic risk in children of peripubertal age.[15] So far, studies linking BP, CRF, and excess weight in young children are limited, and none have explored whether BMI acts as a confounding variable or an intermediate variable in the relationship between CRF and BP.

Usually, BP measurements only include systolic BP (SBP) and diastolic BP (DBP) values, but other measures such as mean arterial pressure (MAP) have also shown to be independent predictors of cardiovascular events in both normotensive or hypertensive adults.[16] However, the relationship between MAP with BMI and adiposity indicators such as waist circumference or percent body fat in children is unclear.[17]

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| BP | Blood pressure |
| BMI | Body mass index |
| CRF | Cardiorespiratory fitness |
| DBP | Diastolic blood pressure |
| MAP | Mean arterial pressure |
| SBP | Systolic blood pressure |

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Thus, the aims of this study were to analyze the relationship between BMI and CRF with BP and to examine whether BMI is a mediating variable in the relationship between CRF and BP in children aged between 4 and 7 years of age.

## Methods

This cross-sectional analysis of baseline measurement data from a cross-over randomized cluster trial (ClinicalTrials.gov: NCT01971840) tested the effectiveness of a multidimensional physical activity program (Movi-Kids) in preventing excess weight in school children aged 4-7 years.[18] The Movi-Kids study included 1604 school children from 21 primary schools (19 public, 2 private) from different towns in the Cuenca and Ciudad Real provinces, Castilla-La Mancha region, Spain. The study was approved by the Clinical Research Ethics Committee of Virgen de la Luz Hospital in Cuenca. To access the schools, the director's and board of governors' approval was requested, and all parents of children in the third grade of preschool and the first grade of primary school were invited to participate in this project. Those who agreed to participate signed the consent form, which could be revoked by the parents or children at any time.

The measurement procedures have been described extensively elsewhere.[18] The variables were measured in each school using standardized conditions by trained researchers. The children were in light clothes and barefoot and were weighed to the nearest 100 g (Seca 861 scales, Vogel and Halke, Hamburg, Germany). Height was measured with a wall-mounted stadiometer (Seca 222, Vogel and Halke) with the children barefoot, standing straight against the wall, and chin parallel to the floor. Weight and height were measured twice at a 5-minute interval. The BMI was calculated as the weight in kilograms divided by the square of the height in meters. Fat mass percentage was obtained simultaneously through an 8-electrode Tanita Segmental-418 bio-impedance analysis system (TANITA Corporation, Tokyo, Japan). Two readings were obtained in the morning, under controlled temperature and humidity conditions, with the child shoeless and fasting after urination and a 15-minute rest. Waist circumference was determined by the average of 2 measurements taken with flexible tape at the waist (at the midpoint between the last rib and the iliac crest) and at the end of normal expiration.

The DBP and SBP were determined twice at a 5-minute interval. These measures were taken for all children between 9:00 and 10:00 a.m. in a silent room at a pleasant temperature with the child at rest 5 minutes before taking the BP. BP was measured by an automatic BP monitor OMROM-M5-I (Omron Healthcare Europe BV, Hoofddorp, Netherlands) using 3 different sized cuffs according to the circumference of the right arm that were placed 2 centimeters above the elbow flexure at heart level with the arm supported and the child sitting.

The MAP was calculated with the following form: $DBP + [0.333 \times (SBP - DBP)]$. The MAP was used in the mediation analysis as a dependent variable, because it allows BP to be used as a single variable and it is used in evaluation protocols and clinical practice.[19]

CRF was evaluated using the Course Navette test (20-meter shuttle run test), a valid and reliable test to measure the maximal aerobic capacity in children.[20] Participants were required to run between 2 lines 20 meters apart, while keeping pace with audio signals emitted from a prerecorded compact disc. The initial speed was 8.5 $kmh^{-1}$, this was increased by 0.5 $kmh^{-1}$ $min^{-1}$ (stage duration = 1 minute).The last one-half stage completed by the child was considered as CRF.

### Statistical Analyses

The distribution of the continuous variables was checked for normality before the analysis, and then we estimated the partial correlation coefficients to examine the relationship between MAP and CRF and with body composition by sex (BMI, percent body fat, and waist circumference), controlling for age.

CRF was categorized as poor (first quartile), medium (second and third quartiles), or good (fourth quartile) as done in previous studies,[15,21] by sex. For boys, the mean values for CRF were: poor, <1 stage; medium, 1-2.5 stages; and good, >2.5 stages. For girls, the mean values for CRF were: poor, <1 stage; medium, 1-2 stages; and good, >2 stages.

BMI was categorized as normal weight, overweight, or obese according to sex- and age-specific child cut-offs defined by International Obesity TaskForce guidelines[22] which are linked with the following BMI cutoffs at 18 years: normal weight, <25 $kg/m^2$; overweight, 25-30 $kg/m^2$; and obesity, >30 $kg/m^2$.

ANCOVA models were used to assess mean differences in the 3 measures of BP (MAP, SBP, and DBP) among categories of BMI and CRF, controlling for age (model 1) and adjusting for age and CRF or BMI depending on the fixed factor (model 2), by sex. Pairwise post hoc hypotheses were tested using the Bonferroni correction for multiple comparisons.

We carried out a mediation analysis to determine if BMI was a mediator between CRF and MAP using the PROCESS macro for SPSS (SPSS Inc, Chicago, Illinois). To address this analysis, we used 2 strategies: (1) nonparametric, as recommended by Preacher and Hayes,[23] using a resample procedure of 10 000 bootstrap samples, and (2) parametric, using the classical Baron and Kenny[24] steps regression method. To test the statistical significance of the mediation effect in the parametric approach we used the Sobel test.[25] Statistical analyses were performed with SPSS-IBM (V.22 SPSS Inc), and the level of significance was set at $P \leq .05$.

## Results

Of the 1604 participants included in the Movi-Kids study, 1534 school children, including 778 boys (50.7%) and 756 girls (49.3%), had valid data (collected September-November 2013). No differences in age or sex were found between children who had valid data and those who did not. **Table I** shows descriptive characteristics (mean ± SD) of the study sample. There were no differences by sex, except for height, weight, waist circumference, DBP, and CRF, where the boys showed higher values ($P < .05$).

Partial correlations between the variables of BP, body composition, and CRF, controlling for age, are shown in **Table II**