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Body mass index, waist circumference, body fat mass, and risk of developing hypertension in normal-weight children and adolescents

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KEYWORDS
Body mass index (BMI);
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Percentage of body fat (PBF);
Hypertension;
Children

Abstract *Background and aims:* We prospectively examined the association between three adiposity indices, including body mass index (BMI), waist circumference (WC), and percentage of body fat (PBF), and risk of hypertension in normal-weight Chinese children.
Methods and results: The current study included 1526 (713 boys and 813 girls) normal-weight Chinese children (age 6–14 years old), who were free of hypertension at baseline (2014). Heights, body weight, WC, and PBF (estimated by bioelectrical impedance analysis) were measured at the baseline. Blood pressure was repeatedly measured in 2014, 2015 and 2016. Hypertension was defined as either high systolic blood pressure and/or high diastolic blood pressure, according to age- and sex-specific 95th percentile for Chinese children. We used Cox proportional hazards model to calculate the association between exposures and hypertension. We identified 88 incident hypertension cases during two years of follow up. High BMI was associated with high risk of developing hypertension after adjusting for potential confounders. The adjusted hazard ratio for hypertension was 2.88 (95% CI: 1.24, 6.69) comparing two extreme BMI quartiles. Each SD increase of BMI ($\approx$1.85 kg/m^2) was associated with a 32% higher likelihood to developing hypertension (Hazard ratio = 1.32; 95% CI: 1.003, 1.73). In contrast, we did not find significant associations between WC or PBF and higher hypertension risk (p-trend >0.2 for both).
Conclusion: High BMI, but not WC and PBF, was associated with high risk of hypertension in normal-weight Chinese children.

Introduction

Although hypertension is common in children and adolescents who are overweight or obese, it is not rare in normal-weight children, with a prevalence ranging from 6.9% to 17.9% across studies [1–4]. Because adult hypertension could originate in childhood [5], early intervention of hypertension in children with normal-weight is significant for public health.

Previous studies have suggested that obesity was associated with high risk of developing hypertension in

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children [6]. However, evidence remains limited regarding whether high levels of adiposity, as assessed by body mass index (BMI), waist circumference (WC), and percentage of body fat (PBF), could still predict high hypertension risk in children and adolescents with normal weight. Previous studies on this topic generated mixed results [7–10]. This could be interpreted by their small sample size [7], cross-sectional study design [10], and failure to control important cofounders (e.g., diet, physical activities and parental factors) [7–10]. Therefore, we conducted a prospective study to comprehensively evaluate the association between diverse adiposity indices (BMI, WC, and PBF) and hypertension risk in 1526 Chinese children and adolescents with normal weight (<85th age- and sex-specific BMI percentile), after adjustment for several potential confounders including age, sex, birth weight, diet, physical activities, sleep, and parental factors.

Methods

Study population

The current study was conducted in five primary schools in Gao Hang Town, Shanghai, China. In 2014 (baseline), all the students (n = 3781) of these schools were invited to participate in a survey, which included anthropometric examination, blood pressure assessment, and a questionnaire. Blood pressure was repeatedly measured in 2014, 2015 and 2016. After excluding children and adolescents with hypertension and missing data, and those who declined to participate in the survey, a total number of 1526 children and adolescents with normal-weight (<85th age- and sex-specific BMI percentile), who were free of hypertension (813 girls and 713 boys, aged 6–14 years) at the baseline, were included in the current study. The details of participant recruitment were in Fig. 1. Parents/caretakers signed informed consent forms. The study was approved by the Ethics Committee of Ren Ji Hospital, School of Medicine, Shanghai Jiao Tong University (AFINS-HOPE- 2013-06).

Anthropometrical data and body fat

Height (to the nearest 0.1 cm), weight (to the nearest 0.1 kg), and body fat (BIA method; TBF-410, Tokyo, Japan) [11,12] were measured with children and adolescents barefoot and in underwear. Body fat was recorded as PBF (fat mass/body weight × 100) to the nearest 0.1%. BMI was calculated as body weight (kg) divided by the height squared (m^2). BIA had been reported to be strongly associated with dual-energy X-ray absorptiometry [12] and underwater weighting [13] for estimation of PBF. Although BIA has not been validated in Chinese children, it was supported to be valid for assessment of PBF by a study conducted among Chinese adults [14]. WC was measured at the midpoint between the iliac crest and the lower rib (to the nearest 0.1 cm) at the end of a gentle expiration in the standing position.

Resting blood pressure (BP)

Resting BP was measured twice on the children's right arm in a quiet room after resting for at least 10 min, using a mercury sphygmomanometer and a special cuff that fit 2/3 of the children's arm. Systolic blood pressure is the point at which the onset of Korotkoff sounds and the fourth Korotkoff sound (K4) was used to define diastolic blood pressure [15]. The interval between the two blood pressure measurements was 10 min and the average value of BP was recorded to the nearest one mmHg. Hypertension was defined as either high systolic blood pressure and/or high diastolic blood pressure, according to the age- and sex-specific 95th percentile for Chinese children [16]. If the child was suspected with hypertension, blood pressure was measured again by another medical staff after another 10-min rest. Average blood pressure was used for the current analysis.

Assessment of covariates

Parents completed the questionnaire including questions on age, sex, birth weight, infant feeding pattern, physical activities, diet, and bedtime. We collected dietary

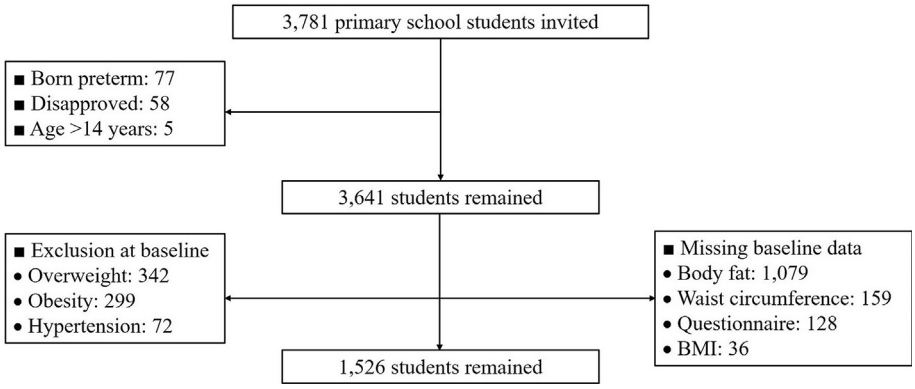

Figure 1 The process of sample recruitment.

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