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Association between leg length-to-height ratio and metabolic syndrome in Chinese children aged 3 to 6 years

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ABSTRACT

Objective. The aim of this study is to investigate the association between leg-length-to-height ratio (LLHR) and metabolic syndrome (MetS) among Chinese children.

Methods. 1236 children (619 obese and 617 nonobese children) aged 3–6 years participated in a cross-sectional survey in 2005 in Tianjin, China. Information on body adiposity, metabolic traits, and related covariates was obtained using a standardized protocol. LLHR was calculated as the ratio of leg length to stature.

Results. In the multivariable logistic regression analyses, compared with those in the lowest quartile, odds ratios (OR) and 95% confidence intervals (CI) of MetS among children in the second through the highest quartiles of LLHR Z-score were 0.89 (95% CI, 0.64–1.25), 0.45 (95% CI, 0.32–0.63), and 0.37 (95% CI, 0.26–0.53), respectively, ($P_{\text{for trend}} < 0.0001$ across LLHR Z-score quartiles). Compared with children with both higher levels of LLHR and lower levels of adipose indices, the corresponding ORs of MetS for those with both lower levels of LLHR and higher levels of anthropometric indices were 4.51 (95% CI, 3.08–6.62) for BMI Z-score, 3.86 (95% CI, 2.60–5.73) for waist circumference, and 2.75 (95% CI, 1.85–4.10) for waist-to-hip ratio, respectively.

Conclusions. Greater LLHR is inversely associated with MetS in Chinese children.

Introduction

A growing body of evidence suggests that pediatric obesity and related metabolic abnormalities have profound implications on risk of cardiometabolic disease in adulthood (Gunnell et al., 1998; Guo et al., 2002; Magnussen et al., 2010). Sinha et al. (2002) reported that there is a significant correlation between obesity and metabolic abnormalities in American children and adolescents. A longitudinal study further revealed that pediatric metabolic syndrome (MetS) was related to severe adult atherosclerosis and an increased risk of type 2 diabetes (T2D) (Magnussen et al., 2010).

Prenatal and postnatal development has been shown to be associated with risk of cardiometabolic disease in adulthood (Barker, 1995). Low birth weight, an indicator of attenuated intrauterine development, has been found to be related to an increased risk of T2D (Kaijser et al., 2009) and CVD (Barker et al., 2005). A recent systematic review (Paajanen et al., 2010) reported that shorter stature in adults is associated with increased risks of CVD morbidity and mortality compared with those with relatively greater stature. There is some evidence suggesting an inverse relation of body height to both insulin resistance (Brown et al., 1991; Davey Smith et al., 2001) and risk of T2D (Njolstad et al., 1998; Sayeed et al., 1997). Several studies (Gunnell et al., 1999; Li et al., 2007; Wadsworth et al., 2002) have shown that leg length, but not trunk length, is the height component that is more sensitive to postpartum environmental exposures during infancy. In contrast, birth weight, a proxy of intrauterine development, has an identical impact on both leg and trunk length growth (Gunnell et al., 1999; Wadsworth et al., 2002). Some studies, including ours, have shown that relatively longer leg length

Abbreviations: BMI, body mass index; CI, confidence interval; CVD, cardiovascular disease; HDL, high-density lipoprotein; LDL, low-density lipoprotein; LLHR, leg-length-to-height ratio; MetS, metabolic syndrome; OR, odds ratios; PI, Ponderal index; T2D, type 2 diabetes; WHR, waist-to-hip ratio.

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(Liu et al., 2009) and greater leg length-to-height ratio (LLHR) (Asao et al., 2006) were associated with a reduced risk of T2D in adults. Further, we observed that greater LLHR was associated with a decreased risk of developing childhood overweight or obesity among Canadian children (Liu et al., 2012). We, therefore, hypothesized that height components might be associated with MetS among children. In this analysis, we aimed to investigate the associations between LLHR and MetS in Chinese children aged 3–6 years. In addition, we evaluated the interactions between LLHR and anthropometric indices of adiposity with respect to metabolic abnormalities among our study participants.

Materials and methods

Study participants

The study design and sampling methods of the Tianjin Children's Health Survey 2005 have been described in detail previously (Tian et al., 2010; Zhang et al., 2009). In brief, the cross-sectional survey was carried out in 71 kindergartens randomly sampled from a total of 269 kindergartens in Tianjin, China from March to September 2005. A multistage cluster sampling was used to obtain a random sample of children aged 3 to 6 years in the city. About 20% of kindergartens (29 kindergartens of 151) were randomly selected from 9 urban districts, and about 35% (42 kindergartens of 118) were randomly selected from 9 rural areas because of their small sizes. All children aged 3 to 6 years in the selected kindergartens were invited to participate in the survey. A total of 15,928 children completed the survey, with a response rate of 95.6% (Zhang et al., 2009). Of them, an age-matched (one-for-one in 1 year increment) case–control study was further conducted to investigate neonatal and postnatal factors associated with childhood obesity and obesity-related metabolic abnormalities (Tian et al., 2010). We used the World Health Organization child growth reference (World Health Organization, 2004) to define obesity and nonobesity. The BMI Z-score cutoff point we used was 1.65, which is the 95th percentile of age-and sex-specific distribution. The cases and controls ($n = 1258$) were those with a BMI Z-score of 1.65 or higher and their age-matched counterparts with a BMI Z-score less than 1.65, respectively. The matching was undertaken in each sampled kindergarten. In total, 1236 children (619 obese and 617 nonobese children) were successfully recruited for the study. The study was approved by the institutional review board of the Tianjin Women and Children's Health Center.

Data collection

Trained health workers undertook the data collection procedures. Before the physical examination, a set of self-administered questionnaires was given to the children's parents to be completed at home (Tian et al., 2010). Parents were also instructed not to give any food or beverages to their child after 8 PM the night prior to the morning physical examination. The physical examination was done between 7:30 and 8:30 AM at the kindergarten clinic unit. When children were brought to clinic by their parents, the self-administered questionnaire was examined by a trained health worker, who was from the Women and Children's Health Center at city or local district levels, to identify any uncertain and incomplete questions from the questionnaire and seek clarification from the parents. After anthropometry and other measurements were taken approximately 0.5-mL sample of peripheral blood was taken from the child's middle finger.

Anthropometric measurements

During the physical examination, weight was measured with a beam-balance scale with subjects wearing light indoor clothing without shoes. Height and sitting height were measured by a stadiometer. Sitting height was measured as the child sitting on the seat straight against the wall of the stadiometer and recorded as the distance between the head piece that was touching the child's head firmly and the seat of the stadiometer. Waist circumference was measured at the level of the umbilicus and hip circumference was measured at the widest point around the left and right greater trochanters. The values of height, sitting height, waist circumference and hip circumference were recorded to 0.1 cm and weight was recorded to 0.1 kg.

Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Ponderal index (PI) was calculated as birth weight in kilograms divided by birth length in meters cubed. Waist-to-hip ratio (WHR) was calculated by dividing waist circumference by hip circumference. Leg-length was determined as the difference between body height and sitting height (Bogin and Varela-Silva, 2010). LLHR was computed as the ratio of leg length to body height: (leg-length / height) $\times$ 100.

Measurements of metabolic traits

Blood pressure was measured using a standardized mercury sphygmomanometer with an appropriate cuff bladder for children. The fourth Korotkoff sound was adopted for diastolic blood pressure recording. The measurement was taken on the right arm of the participant in a comfortable sitting position after at least 5 minutes' rest. Mean blood pressure was calculated from 2 readings unless the difference between these readings was greater than 10 mm Hg, in which case a third measurement was taken and the mean of the last 2 measurements was used.

Serum fasting glucose, total cholesterol, high-density lipoprotein (HDL)-cholesterol, low-density lipoprotein (LDL)-cholesterol, and triglycerides were measured on an automatic analyzer (RX Daytona; Randox Laboratories Ltd, Antrim, Ireland) with reagents purchased from the manufacturer.

Definition of metabolic syndrome

In this analysis, the pediatric MetS was defined as having three or more of the following components: 1) waist circumference $\geq$75 percentile of age- and sex-specific waist circumference distribution (Fernandez et al., 2004); 2) triglycerides $\geq$0.85 mmol/L; 3) HDL cholesterol <1.55 mmol/L (Jolliffe and Janssen, 2006); 4) either systolic or diastolic blood pressure $\geq$75 percentile age-, sex-, and height-specific blood pressure distribution (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004); and 5) fasting glucose $\geq$5.6 mmol/L (Magnussen et al., 2010).

Assessment of covariates

Parents' educational attainment was categorized into three groups: 9 years or less, 10 to 12 years, and 13 years or more. Both mother's and father's BMI were derived from information of weight and height collected in the self-administered questionnaire. Based on the responses to relevant questions from the questionnaire, the following categorical variables were created and dichotomized as yes or no: breast-feeding at age of 12 months, complementary food introduction before age of 6 months, sleep duration less than 9 h, sweetened beverage consumption more than 500 ml/week, high-fat meat intake defined as if fat content was more than half of total meat, everyday intake of vegetables and fruits, duration of television viewing 60 minutes/day or more, and duration of any type of physical activity 30 min/day or less. Disease status was classified as yes for 13 participants who reported having pneumonia, cold, or fever during the past 30 days (Tian et al., 2010).

Statistical analysis

In order to account for age and sex differences in LLHR, we computed age- and sex-specific standard deviation scores (Z-score) of LLHR for