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Original Article

Age- and Sex-Dependent Values of the Distribution of Body Composition Parameters Among Chinese Children Using the Hattori Chart

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Abstract

This study aimed to examine the relationship between the fat-free mass (FFM) and fat mass (FM) and between the fat-free mass index (FFMI) and fat mass index (FMI) in Chinese children using the Hattori chart and to compare the changing pattern with Korean counterparts. In this study, 1541 (764 girls) children and adolescents aged 5–19 yr were recruited from southern China. The subjects' body composition was measured using dual-energy X-ray absorptiometry. The relationship between FFM and FM and between FFMI and FMI were delineated using the Hattori chart. Between 5 and 12 yr, a concurrent increase in FFM and FM and in FFMI and FMI was found in both sexes. After 12 yr, the age-related changing patterns are generally characterized by a sharp increase in FM, with a relatively small increase in FFM for girls, and a sharp increase in FFM, with a relatively little fluctuation in FM for boys. The increase in weight and BMI with age for this stage is largely due to the increase in FFM and FFMI in boys and in both the FFM and FM and FFMI and FMI components in girls. Sex differences in the patterns of body composition were found in Chinese children and adolescents.

Key Words: BMI; Chinese children; fat mass; Hattori chart.

Introduction

With the recent economic development and lifestyle changes in China, childhood obesity is becoming a major public health concern *(1)*. Body mass index (BMI) values are often used to define overweight and obesity in children. However, this measure is limited by its failure to distinguish between fat-free mass (FFM) and fat mass (FM), which can result in significant misclassification *(2)*. Furthermore, the significance of BMI measurements is not always clear because a given BMI can include a wide range of fat and a change in BMI does not reflect a change in adiposity during childhood *(3,4)*. Another limitation of BMI as an index of body composition is that varying amounts of adiposity for a given BMI value are observed across ethnic groups *(5,6)*. In 1990, VanItallie et al proposed splitting BMI into 2 components: the fat-free mass index (FFMI; FFM/height^2) and the fat mass index (FMI; FM/height^2), each expressed in the same kilogram per square meter units as BMI *(3)*. The concept of FFMI and FMI, analogous to the BMI but using a 2-compartment model, merits a reappraisal and appears to be of interest in the classification of overweight and obesity children.

Currently, there are a number of methods developed to assess body composition *(7)*, such as skinfold thickness, bioelectric impedance analysis, dual-energy X-ray absorptiometry (DXA), and magnetic resonance imaging, among others. In these methods, DXA has gained wider acceptability as a research tool for the evaluation of body composition because it provides a precise body composition analysis that has high precision, low scanning time, and low radiation exposure (5–10 μSv) *(8,9)* and is able to detect

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small changes in body composition in children *(10)*. Thus, DXA is considered to be one of the most precise and applicable methods for the measurement of body composition in pediatric populations.

Hattori's body composition charts showed body composition to be a quantitative measure by placing FFM (FFMI) and FM (FMI) on each axis of the chart. Furthermore, the total fat mass percentage (total FM%) and BMI were overlaid to elaborate body composition in relationship to anthropometry. Application of the charts provides the opportunity to investigate the nature of weight and BMI gain with age and the drawbacks of the use of BMI in the assessment of adiposity in healthy children *(11)*. On this basis, Hattori charts can also be used in clinical monitoring to detect individual abnormalities in growth trajectory *(12,13)*. In the literature reviewed, Hattori's body composition charts have been published according to different methods for the assessment of body composition *(11,14–19)*. To the best of our knowledge, no large samples of Hattori's body composition charts with DXA in Chinese children and adolescents have been published. Thus, there is a need for the generation of Hattori's body composition charts of Chinese youth for the early detection of childhood overweight and obesity.

Thus, the objective of the current study was to provide age- and sex-specific Hattori body composition charts in Chinese children and adolescents aged 5–19 yr, as assessed using DXA data. In addition, our data can be compared with those of Korean counterparts in the same age period.

Materials and Methods

Subjects

This study sample consisted of 1541 (777 boys and 764 girls) healthy Chinese school children and adolescents aged 5–19 yr who were recruited from 4 local schools in the urban area of Guangzhou district and from 1 school in the urban area of Jiaxing district in southern China between January 2007 and June 2011. All subjects were transported to the study center (Department of Nuclear Medicine of the First Affiliated Hospital, Jinan University, Guangzhou) for body composition assessment by DXA. All participating children and adolescents were of Han nationality and were born and still live locally. The participants included in the study were between the 3rd and 97th percentiles in height, weight, and BMI based on current growth reference curves *(20,21)*, and these students were assessed based on the BMI reference norm for screening overweight and obesity in Chinese children and adolescents by the Working Group on Obesity in Chinese *(22)*.

The subjects who participated in the present study completed a screening questionnaire, and medical examinations were performed by a trained pediatrician to assess the children's health statuses, and those with overt disease or physical/mental deformities were excluded. The schools required the children to have outdoor exercise for approx 1 h each day, and none of the participants had undertaken long-term intensive sports training and used calcium-containing drugs or health products. Written informed consent was obtained from all participants and their parents. The present study was approved by the Ethics Committee of the First Affiliated Hospital, Jinan University (No. 2007-4T47).

Anthropometric and DXA Measurements

Anthropometric and DXA measurements were obtained from the children and adolescents during a single visit. Weight was measured using platform digital scales with a precision of 0.1 kg, and standing height was recorded with a stadiometer to the nearest 0.1 cm. Total body composition, including the bone mineral content (BMC, in gram), lean mass (LM, in kilogram), and FM (in kilogram), was measured using a Lunar Prodigy DXA bone densitometer (GE Healthcare, Madison, WI), and the data were analyzed using enCORE software (version 10.0, standard-array mode, GE Healthcare, Madison, WI). The test–retest short-term precision errors for the total body BMD, BMC, FM, and LM measurements were 0.50%, 1.05%, 1.95%, and 0.93% (expressed as the root-mean-square percent coefficient of variation), respectively, as determined by duplicate scans with repositioning between each measurement in 30 volunteer subjects. Daily quality assurance scans were performed by scanning an aluminum spine phantom according to the manufacturer's instructions. All of the DXA measurements were performed by a well-trained technologist throughout the study. Total body FFM was measured by DXA as the total body BMC in addition to total body LM *(23)*. We calculated the total FM% by dividing the total FM (in kilogram) by weight (in kilogram), FMI (in kilogram per square meter) by dividing the total FM (in kilogram) by height (in square meter), and FFMI by dividing FFM (in kilogram) by height (in square meter).

Hattori's body composition charts were drawn using a previously described procedure *(18)*. Two types of body composition charts were used in the present study. First, the means of FFM and FM of every age group were plotted (body composition chart 1). The FFM and FM were placed on the *x*- and *y*-axes, respectively. Because the sum of FM and FFM equals the body weight, and the total FM% equals FM/(FM + FFM), the body weight and total FM% were added as diagonal lines. The means of FFMI and FMI for boys and girls are plotted on body composition chart 2. The *x*- and *y*-axes represent the FFMI and FMI, respectively, with additional diagonal lines indicating BMI and the total FM%.

Hattori's body composition charts of the Chinese children and adolescents were compared with those of Korean children using the Hologic QDR 4500A fan-beam DXA scanner *(24)*. The Korean subjects (834 for boys and 745 girls) aged 10–18 yr were participants in the 2009–2010 Korea National Health and Nutrition Examination Survey, which was a nationwide cross-sectional survey by the Ministry of Health and Welfare and the Korea Centers for Disease Control and Prevention. To reduce the differences between the GE Healthcare Lunar and Hologic whole-body scans, we used the recommended cross-calibration equations from