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Original article

Waist-to-height ratio, waist circumference and BMI as indicators of percentage fat mass and cardiometabolic risk factors in children aged 3–7 years

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SUMMARY

Objective: To assess whether waist-to-height-ratio (WHtR) is a better estimate of body fat percentage (BF%) and a better indicator of cardiometabolic risk factors than BMI or waist circumference (WC) in young children.

Methods: WHtR, WC and BMI were measured by trained staff according to standardized procedures. ^2H_2O and $^2H_2^{18}O$ isotope dilution were used to assess BF% in 61 children (3–7 years) from the general population, and bioelectrical impedance (Horlick equation) was used to assess BF% in 75 overweight/obese children (3–5 years). Cardiometabolic risk factors, including diastolic and systolic blood pressure, HOMA2-IR, leptin, adiponectin, triglycerides, total cholesterol, HDL- and LDL-cholesterol, TNFα and IL-6 were determined in the overweight/obese children.

Results: In the children from the general population, after adjustments for age and gender, BMI had the highest explained variance for BF% compared to WC and WHtR ($R^2 = 0.32$, 0.31 and 0.23, respectively). In the overweight/obese children, BMI and WC had a higher explained variance for BF% compared to WHtR ($R^2 = 0.68$, 0.70 and 0.50, respectively). In the overweight/obese children, WHtR, WC and BMI were all significantly positively correlated with systolic blood pressure ($r = 0.23$, 0.30, 0.36, respectively), HOMA2-IR ($r = 0.53$, 0.62, 0.63, respectively), leptin ($r = 0.70$, 0.77, 0.78, respectively) and triglycerides ($r = 0.33$, 0.36, 0.24, respectively), but not consistently with other parameters.

Conclusion: In young children, WHtR is not superior to WC or BMI in estimating BF%, nor is WHtR better correlated with cardiometabolic risk factors than WC or BMI in overweight/obese children. These data do not support the use of WHtR in young children.

1. Introduction

Various measures are used to detect obesity – defined in terms of excess body fat – and the risk of obesity-related co-morbidities. Body mass index (BMI) is the most commonly used measure, but waist circumference (WC) and waist-to-height ratio (WHtR) as measures of abdominal fat are also used. WHtR may have an advantage over BMI because BMI provides no information about body fat distribution, in particular abdominal fat. Central fat distribution is associated with greater health risks than total body fat.[1,2] Therefore, WHtR may be a better indicator of cardiometabolic risk factors than BMI. In adults, WHtR is found to be a better measure than BMI and WC for the prediction of obesity-related cardiometabolic risks factors.[3,4] An advantage of WHtR over BMI and WC in adults is that a general cut-off value of 0.5 can be used for both men and women across many ethnicities.[3,4] Moreover, the advantage of WHtR over WC is that WHtR adjusts for height. When compared to short people with the same WC, tall people have lower levels of cardiometabolic risk factors and a 30% lower prevalence of the metabolic syndrome.[5]

WHtR decreases from birth to the age of five from 0.69 to 0.48,[6] and this decrease continues until early adolescence to 0.40–0.41.[7] From then on it increases slightly to 0.42–0.43 towards the age of 18. Therefore, one cut-off value for all ages during childhood and adolescence is not feasible.[6,7] In contrast to adults, it is less clear in young children whether WHtR is better than BMI or WC in

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predicting obesity-related cardiometabolic risk factors. Most of the studies available evaluated the relationship between WHtR and body fat percentage (BF%) or cardiometabolic risk factors over a large age range, including both children and adolescents, with most studies using children aged 6 years or older. To prevent overweight and obesity in adolescents and adults, early detection of overweight and obesity in young children is needed. During early childhood especially (2–6 years of age), excessive BMI gain is predictive of obesity and cardiometabolic risk in adolescence[8] and adulthood.[9–11] Furthermore, adipose tissue produces cytokines, like IL-6 and TNFa, which may cause metabolic syndrome, this is already seen in children.[12] These cytokines may be a possible link between insulin resistance and adiposity. Increased levels of the separate components of metabolic syndrome have already been demonstrated in children 6–9 years old.[13] In children aged younger than 6 it is unknown whether these processes are present yet.

Few studies have examined the association between WHtR and BF%[14,15] or cardiometabolic risk factors[15–17] in children aged younger than 6 years. Of the three studies investigating the associations between WHtR and cardiometabolic risk factors in children aged younger than 6 years, only one study analysed the associations between WHtR and more than one cardiometabolic risk factor. Moreover, these studies lack information about overweight/obese children, despite these children being the target group for treatment programmes.

The aim of this study is to assess whether WHtR is a better estimate of BF% than BMI and WC in very young non-obese and obese children (3–7 years of age), and whether it is a better indicator of obesity-related cardiometabolic risk factors.

2. Materials and methods

2.1. Subjects

Three groups of children were included in this study. The first group consisted of children ($n = 30$) from the general healthy Dutch population, 3–4 years of age, who were randomly selected from the GECKO Drenthe cohort.[18] Data were collected between March 2010 and March 2011. The second group consisted of children ($n = 31$) from the general healthy Dutch population, 6–7 years of age. These children were recruited through advertisements in a local newspaper and on the hospital information site, and by word of mouth. Data were collected in October 2006 and have been partly described in previous studies.[19,20] In these two groups, children having medical problems which could affect physical activity, and children diagnosed with a disease or using medication known to affect body composition were excluded from the study. These two groups were combined as one group of children from the general population. The third group consisted of overweight/obese children ($n = 75$), 3–5 years of age, who were part of a randomized controlled clinical trial (GECKO Outpatients Clinic) aimed at reducing overweight.[21] The baseline data of the participants were used for this analysis and were measured during the children's first visit to the hospital. Data were collected between October 2006 and March 2008. Only children with overweight or obesity, according to the International Obesity Task Force (IOTF) definitions[22] were included. Children with overweight or obesity due to known medical conditions or eating disorders according to the Dutch Eating Behaviour Questionnaire, mental retardation, severe behavioural problems or other criteria interfering with participation were excluded. Almost all of the children were Caucasian, one child from the first group had an Asian father and two children had African parents (one in the second and one in the third group). Written informed consent was obtained for all children, and the studies were approved by the Medical Ethics Committee of the University Medical Center Groningen (UMCG).

2.2. Body composition

In all children, height to the nearest 0.1 cm and weight to the nearest 0.1 kg were measured without shoes in light clothing using a stadiometer and a calibrated digital scale, respectively. BMI was calculated as weight/height^2. WC was performed with a standard tape measure and recorded to the nearest 0.1 cm in standing position. WC was measured at the mid-point between the lower costal margin and the level of the anterior superior iliac. BF% was measured using different methods for the three groups. In the first group (3–4 years of age from the general population), BF% was determined by the $^2H_2^{18}O$ isotope dilution method. Children drank a weighted amount (around 50 grams) of doubly labelled water (Buchem, Apeldoorn, the Netherlands [^2H_2O: 6.02%, $H_2^{18}O$: 12.05%]; Campro Scientific, Berlin, Germany [^2H_2O: 6.63%, $H_2^{18}O$: 11.50%]). Saliva samples were collected by the parents before administration and approximately 4, 16, 72 and 120 h after administration. Total body water (TBW) was determined from the dilution spaces of both isotopes. The component TBW in fat free mass (FFM) was set at 0.775 for the 3-year-old boys, 0.770 for the 4-year-old boys, 0.779 for the 3-year-old girls, and 0.777 for the 4-year-old girls.[23] BF% was calculated as ([weight-FFM]/weight) * 100. More detailed information is described elsewhere.[24] In the second group (6–7 years of age from the general population), BF% was calculated from TBW, determined by an orally administered dose of 99.8% ^2H_2O of 0.15 g per kilogram body weight. Detailed information about the method has been described before.[20] In the third group (3–5 years of age overweight/obese children), BF% was estimated using a 50 kHz fixed frequency hand-to-foot bio-impedance analyzer (BIA-101, Akern S.r.l./RJL Systems, Florence, Italy). The measurements were performed three times and the average calculated. The resistance (R_z) value from BIA together with height, weight, age and sex were used to calculate the FFM using the Horlick equation.[25] BF% was calculated as ([weight − FFM]/weight) × 100.

2.3. Overweight/obesity-related cardiometabolic risk factors

Cardiometabolic risk factors were only measured in the overweight/obese group. Systolic and diastolic blood pressures were measured in supine position at the right upper arm with a Dinamap Critikon 1846SX digital sphygmomanometer (Critikon Inc., Tampa, Florida, USA) and an appropriate cuff size. The child was instructed not to speak or move during the measurements. The mean of two measurements was calculated. Blood was drawn after an overnight fast. An enzymatic colorimetric method (Roche Modular, Basel, Switzerland) was used to determine total cholesterol, high-density lipoprotein (HDL)-cholesterol, low-density lipoprotein (LDL)-cholesterol and triglycerides. The updated homeostasis model assessment of insulin resistance (HOMA2-IR) was used to calculate insulin resistance.[26] HOMA2-IR was calculated from fasting plasma glucose and fasting plasma insulin, determined by enzymatic method (hexokinase-mediated reaction, Roche Modular, Basel, Switzerland) and radioimmunoassay (Diagnostic Systems Laboratories, Inc., Webster, TX, USA), respectively. Serum levels of leptin, interleukin-6 (IL-6) and tumour necrosis factor-alpha (TNFα) were measured by a combination enzyme-linked immunosorbent assay (ELISA; Milliplex Map Human Adipokine Panel B, Millipore, St. Charles, MN, USA). Serum levels of adiponectin were quantified by ELISA (Millipore, St. Charles, MN, USA).

2.4. Statistics

Mean and standard deviations were calculated for all of the characteristics measured. Univariate linear regression analyses were performed with BF% as the dependent variable and WHtR, WC