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Using weight-for-age percentiles to screen for overweight and obese children and adolescents

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ABSTRACT

There are relatively low rates of screening for overweight and obesity among children and adolescents in primary care. A simplified method for such screening is needed. The study objective was to examine if weight-for-age percentiles are sufficiently sensitive in identifying overweight and obesity in children and adolescents.
We used data from two distinct sources: four consecutive cycles of the National Health and Nutrition Examination Surveys (NHANES) from the years 2005 to 2012, using participants aged 2–17.9 years for whom data on age, sex, weight, and height were available ($n = 12{,}884$), and primary care clinic measurements ($n = 15{,}152$). Primary outcomes were the threshold values of weight-for-age percentiles which best discriminated between normal weight, overweight, and obesity status.
Receiver operating characteristic analyses demonstrated that weight-for-age percentiles well discriminated between normal weight and overweight and between non-obese and obese individuals (area under curve = 0.956 and 0.977, respectively, both $p < 0.001$). Following Classification and Regression Trees analysis, the 90th and 75th weight-for-age percentiles were chosen as appropriate cutoffs for obesity and overweight, respectively. These cutoffs had high sensitivity and negative predictive value in identifying obese participants (94.3% and 98.6%, respectively, for the 90th percentile) and in identifying overweight participants (93.2% and 95.9%, respectively, for the 75th percentile). The sensitivities and specificities were nearly identical across race and sex, and in the validation data from NHANES 2011 to 2012 and primary care.
We conclude that weight-for-age percentiles can discriminate between normal weight, overweight and obese children, and adolescents. The 75th and 90th weight-for-age percentiles correspond well with the BMI cutoffs for pediatric overweight and obesity, respectively.

Introduction

Childhood obesity is a major health concern, as evidenced by nearly 32% of American children and adolescents being overweight or obese (Ogden et al., 2014). Increased body mass index (BMI) in childhood and adolescence is associated with increased risks of adulthood diabetes, coronary heart disease, and even death (Tirosh et al., 2011; Franks et al., 2010; Must et al., 2012). Thus, pediatric overweight and obesity continue to be a major focus of public health efforts worldwide. A key issue in prevention and treatment of these conditions is the need to identify the children that have excess adiposity.

BMI is the tool currently recommended to define overweight and obesity by major pediatric obesity guidelines (Krebs et al., 2007; Baker et al., 2010), mainly due to its simplicity. While there is a known, imperfect association between BMI and the amount of body fat, a high BMI has a moderately high sensitivity and positive predictive value, along with a high specificity, for excess body fatness (Freedman and Sherry, 2009).

The use of BMI for identifying overweight and obese children was advocated by an expert committee of the American Society for Clinical Nutrition in 1994 (Himes and Dietz, 1994). The committee acknowledged that several weight indexes exist, that many represented acceptable indicators of overweight, obesity, and body fat, and that they were frequently highly correlated with each other. Current weight-for-age percentile curves were not available at that time.

Despite the relative simplicity of obtaining weight and height measurements from children in a clinical setting, even with automatic BMI calculations and graphic display of percentiles in computerized medical records, physicians are still performing poorly in overweight and

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obesity screening, even well within the current obesity epidemic. In one recent study, less than 50% of all primary care physicians assessed BMI percentiles regularly in children (Huang et al., 2011). In another study based on a national survey, 50% of 250 pediatricians, and only 22% of 621 general practitioners, used BMI-for-age measurements to screen for obesity at every well-child visit (Wethington et al., 2011). Reasons for the low rate of BMI measurements in a busy primary care clinical setting could very well be the time, effort, and equipment needed to adequately measure height, as well as the difficulty of explaining the BMI concept (Woolford et al., 2008). In one study, the main identified barriers to using BMI charts at preschool well-child visits were the time to calculate and plot BMI (perceived by 65% of all respondents), and the time and complexity involved in explaining the findings of BMI to parents (perceived by 70% of all respondents) (Woolford et al., 2008). Therefore, we were driven to find a simple method in order to initially screen for overweight and obesity in children and adolescents. We hypothesized that measuring weight alone and using the weight-for-age percentile curves may be a sufficiently sensitive screening method to identify overweight and obesity status in the pediatric age range.

The study aims were to examine the relationship between weight-for-age percentiles and BMI-for-age percentiles and to identify the weight-for-age percentiles that best correspond with current BMI definitions of overweight and obesity and their discriminative ability.

Methods

The data for this study were obtained from two sources. The first source was the National Health and Nutrition Examination Survey (NHANES), which is an ongoing population-based survey designed to assess the health and nutritional status of adults and children in the United States. The NHANES is conducted by the National Center for Health Statistics, which is part of the Centers for Disease Control and Prevention (CDC), and its data sets are available online for research purposes (http://www.cdc.gov/nchs/nhanes.htm, 2015). Four consecutive NHANES cycles were used, from the years 2005–2006, 2007–2008, 2009–2010, and 2011–2012. The first three NHANES cycles were used as a training set, and data from NHANES 2011 to 2012 were used for validation. Data extracted for the purpose of this study from the database were age, race, sex, weight, and height. Only children and adolescents aged 2–17.9 years that had all data variables (age, sex, weight, and height) were included. NHANES sample weights were not used for two reasons. First, the purpose of this study was not to provide estimates of obesity and overweight prevalence in the American population, but merely to correlate weight and BMI using a large and rigorous database. Second, we preferred to use actual measured data for our comparisons, in similarity to what is done in clinical practice. We did perform weighting to the NHANES 2011–2012 validation set, in order to obtain more accurate estimates of the American population. The second source of data was a community healthcare service in Israel, serving 720,000 people ("Leumit" Health Care, Israel). Data from this database were available for children and adolescents aged 10–17.9 years. Weight-for-age and BMI-for-age were transformed to their corresponding percentiles according to the CDC reference curves (which are recommended for use from age 2 and above in the United States) using the LMS type approach (Flegal and Cole, 2013). The study participants were categorized into three groups according to their BMI status: normal weight, overweight (defined as having a BMI ≥ 85th but <95th percentile for sex and age), and obese (defined as having a BMI ≥ 95th percentile for sex and age) (Krebs et al., 2007). The study was approved by the Institutional Review Board of Sheba medical Center, Tel Hashomer, Israel.

The concordance correlation coefficient (Lin, 1989) was used to measure the agreement between weight-for-age percentiles and BMI-for-age percentiles in the study population and its deviation from a perfect 1:1 diagonal line. Receiver operating characteristic (ROC) was used to evaluate the discrimination ability of weight-for-age percentiles between participants with normal weight vs. those with overweight and obesity, and between non-obese vs. obese participants. Classification and Regression Trees (CART) analysis (Breiman et al., 1984) was used to search for the threshold values of weight-for-age percentiles that optimally divided participants by normal weight, overweight, and obesity status. In brief, this automated algorithm divided the data into two groups which are homogenous as much as possible, and that differ from each other as much as possible, based on the requested target value. This enabled us to identify the optimal cutoff value between designated groups, as determined by the user. After identifying the optimal cutoffs of weight-for-age percentiles to discriminate between normal weight, overweight, and obese participants, we calculated the sensitivity, specificity, negative predicted value, and positive predicted values of the newly identified cutoffs in identifying overweight and obese participants. This procedure was performed first for the training set of data, and then for the validation sets of data from NHANES 2011 to 2012 and the community clinics.

Categorical variables are presented as frequency and percentage. Continuous variables are presented as mean ± standard deviation (SD), median, inter-quartile range (IQR), and range. IBM SPSS Statistics software version 21 was used for data analysis. R version 3.0.3 (available at http://www.r-project.org, package "epiR") was used to measure the concordance correlation coefficient (Pearson's correlation coefficient and the bias correction factor). A two-tailed p value of <0.05 was considered as statistical significance.

Results

Data on age, sex, weight, and height was available for 9,813 participants from the three NHANES cycles in the years 2005–2010, for 3,071 participants from the NHANES cycle of 2011–2012 used for validation, and for 15,152 adolescents from the community healthcare service.

Table 1 presents the anthropometric characteristics of the study participants from the NHANES cycles of 2005–2010, which were used for the primary part of the study. According to current BMI definitions, 66.1% of study participants were of normal weight status, 15.2% were overweight and non-obese, and 18.7% were obese.

Fig. 1 presents the association between weight-for-age percentiles and BMI-for-age percentiles in the study population. A high correlation was found between the two parameters (Pearson's $r = 0.855$, 95% confidence interval 0.850–0.860, $p < 0.001$). The bias correction factor was 0.999, signifying only a negligible deviation from a 45° diagonal

Table 1
Demographic and clinical characteristics of the study participants used for the training data set from NHANES 2005–2010 and the validation data sets from NHANES 2011-2012 and the clinical setting.

	NHANES 2005–2010 ($n = 9{,}813$)	NHANES 2011–2012 ($n = 3{,}071$)	Clinical setting ($n = 15{,}152$)
Age (years)			
Mean ± SD	9.8 ± 4.7	8.8 ± 4.5	16.4 ± 1.0
Median (IQR)	9.7(5.5–13.9)	9.0 (5.0–13.30)	17.0 (16.1–17.1)
Range	2.0–17.9	2.0–17.9	10–17.9
Weight (kg)			
Mean ± SD	40.6 ± 23.9	38.3 ± 22.13	62.6 ± 14.8
Median (IQR)	35.2 (20.3–56.4)	32.3 (19.8–52.5)	60.0 (52.8–70.0)
Range	9.8–215	9.6–138.5	22.5–185.8
Weight (percentiles)			
Mean ± SD	62.9 ± 29.9	1.9 ± 30.0	53.7 ± 30.0
Median (IQR)	68.8 (38.6–90.7)	66.6 (37.4–89.8)	55.2 (28.4–80.7)
Range	0–100	0–100	0–100
Height (cm)			
Mean ± SD	136 ± 27.3	134 ± 26.2	167 ± 9.5
Median (IQR)	138 (113–159)	134 (112–156)	167 (160–174)
Range	79–198	82–194	98–200
Height (percentiles)			
Mean ± SD	54.4 ± 29.0	54.7 ± 29.7	43.9 ± 28.6
Median (IQR)	56.4 (30.5–80.2)	56.7 (29.1–81.6)	40.9 (19.2–67.6)
Range	0–100	0–100	0–100
BMI (kg/m^2)			
Mean ± SD	19.9 ± 5.4	19.4 ± 5.1	2.3 ± 4.4
Median (IQR)	18.2 (16.0–22.2)	17.8 (15.8–21.6)	21.5 (19.4–24.2)
Range	11.7–62.1	12.4–50.7	11.6–63.7
BMI (percentiles)			
Mean ± SD	63.7 ± 29.9	2.3 ± 30.1	56.9 ± 29.9
Median (IQR)	70.0 (40.1–91.6)	67.7 (38.6–90.7)	59.0 (30.9–82.9)
Range	0–100	0–100	0–100

BMI—body mass index.