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High Body Mass Index Percentile Accurately Reflects Excess Adiposity in White Girls

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ABSTRACT

Registered dietitians routinely screen children for overweight and obesity using an age-specific body mass index (BMI) percentile. However, BMI percentile may not be an accurate tool for detecting elevated relative fat mass. The purpose of this study was to assess the validity of BMI percentile for identifying "overfatness" in a cohort of 197 white, 9-year-old girls followed for 6 years during 2000-2007. Height, weight, and relative fat mass data from dual x-ray absorptiometry were collected every 2 years, comprising 695 observations of BMI to relative fat mass relationships. Using receiver operating characteristic analysis and age- and sex-specific cutoff values for relative fat mass from the literature, BMI percentile cutoff values could be identified to screen for girls who were considered "overfat" and "obese" with a high sensitivity (69% to 96%) and specificity (83% to 96%). The Centers for Disease Control and Prevention's BMI cutoff values decreased sensitivity (0 to 76%), but improved specificity (96% to 100%), which may be preferable. Increases in BMI percentile tended to be indicative of increasing adiposity only in girls with a BMI >30th to 40th percentile for age. This study suggests that white girls aged 9 to 15 years with a BMI ≥85th percentile and/or girls with a BMI ≥50th percentile experiencing upward crossing of percentile bands are likely to have excess body fat levels and are good candidates for healthy lifestyle interventions.

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Body mass index (BMI), which is the ratio of weight in kilograms to height in meters squared, has become the standard tool for surveillance and screening of childhood overweight and obesity in the United States (1). Researchers and clinicians generally agree that BMI is a useful tool for surveillance, using the information to monitor the health of a population. The validity of BMI for screening, which is using BMI to diagnose overweight and obesity in individuals, has been intensely debated. In particular, clinicians and researchers are still debating the validity of BMI for detecting underlying adiposity (2,3). This debate has "trickled down" to parents through the media, resulting in a distrust of this method of screening and even outright refusal to accept BMI information as a valid indicator of obesity and/or health (4). As physicians frequently do not discuss weight status with parents (1), registered dietitians (RDs) and dietetic technicians, registered (DTRs) should be prepared to answer parents' questions about what BMI means, its health implications, and its validity during follow-up sessions for lifestyle counseling (1,5).

The goal of this study was to examine the validity of BMI percentile, the most common weight status screening tool for clinicians, for detecting underlying obesity in a sample of white girls aged 9 to 15 years with a broad range of BMI percentile and relative fat mass values. When assessing the validity of BMI percentiles, a developmentally appropriate definition of excess relative fat mass was used as the criterion. Based on previous research (2), we hypothesized that BMI percentile cutoff values could be identified to screen for girls with excess relative fat mass, and increases in BMI percentile would be indicative of increasing relative fat mass in girls with a BMI >50th percentile, but not necessarily for girls <50th percentile.

METHODS

Participants

Participants were drawn from a 10-year longitudinal study of familial, physiological, and genetic factors related to dieting and overweight in young white girls from central Pennsylvania. The initial sample included 197 5-year-old girls (mean age 5.4±0.4 years) and their parents. Eligibility criteria for girls' participation at the time of recruitment included living with both biological parents, the absence of severe food allergies or chronic medical problems affecting food intake, and the absence of dietary restrictions involving animal products. Families were not recruited based on weight status or concerns about weight. Families were recruited for participation through flyers, newspaper advertisements, and a commercial marketing service (Metromail Limited, Kent, CT) targeting families with age-eligible female children within a five-county radius of The Pennsylvania State University. Data are presented for girls aged 9 to 15 years with complete height, weight, and body composition data at study visits, which comprise 695 total observations.

Girl's pubertal development information was collected (breast development subscale of Tanner Scale), but this information was not included in the analyses for two reasons. First, because of the way staging is graded, there was minimal variation between girls at each age (eg, stage 3 vs stage 4). Second, between-age differences in puberty were not considered as the Centers for Disease Control and Prevention's (CDC) recommended screening procedures do not take Tanner stage (or puberty) into account. As weight accretion (increases in BMI) during puberty in girls is largely a function of increased fat mass (2) and early puberty is a risk factor for later obesity, increases in BMI associated with early puberty would be accurately captured in the "at-risk" group.

Research Design

The girls visited the laboratory every 2 years during the summer for collection of a variety of physical and psychological data. Parents provided consent for their family's participation and study procedures at each study visit. The Pennsylvania State University Institutional Review Board approved all study procedures. These data were collected between 2000 and 2007.

Anthropometry. Height and weight measurements were collected in triplicate at each study visit using standard measurement techniques (6). Height was measured to the nearest 0.1 cm with a portable wooden stadiometer (Shorr Measuring Board Stadiometer, Shorr Productions, Irwin Shorr, Olney, MD) and weight was measured to the nearest 0.1 kg using a professional-grade electronic scale (Tanita, Arlington Heights, IL). BMI, the ratio of weight in kilograms to height in meters squared, was calculated from the average height and weight at each visit. The intra-rater reliability across all staff, all measures of height and weight, and at all time points exceeded 0.99.

Body Composition. Absolute fat mass (in kg) and relative fat mass were measured using a Hologic QDR 4500W (S/N 47261) dual-energy x-ray absorptiometry scanner (Hologic Inc, Bedford, MA). Whole body scans were completed using the array scan mode and were analyzed using the most current whole body software at each visit (QDR4500 Whole Body Analysis v8.26a:5 at 9 and 11 years, v12.3 at 13 years, v12.5 at 15 years). Fat mass and relative fat mass are directly generated by the software.

Statistical Analysis

Data are presented as mean±standard deviation unless otherwise noted. The NutStat module of the CDC EpiInfo program was used along with participants' sex, age in months, weight (kg), and height (cm) to derive percentiles for BMI-for-age. All analyses were performed using SAS (version 9.1, 2003, SAS Institute, Cary, NC).

Receiver operating characteristic (ROC) curve analysis was completed using MedCalc (version 9.3.9.0, 2007, MedCalc Software, Mariakerke, Belgium) to assess the ability of BMI percentiles to appropriately classify overfat and obese girls (7). First, girls were classified as "overfat" and "obese" using previously published age-specific normative body fat data (8). Overfat corresponded to being at or greater than the age-specific 85th percentile for relative fat mass, and obese corresponded to being at or greater than the age-specific 95th percentile for relative fat mass (8). Then, the true-positive rate (sensitivity) was plotted in function of the false-positive rate (100-specificity) for all BMI percentile values (ROC curve). The criterion value, the BMI percentile that optimizes the balance between true-and false-positive rates for detecting both overfat and obese, was determined. Last, the area under the ROC curve was calculated. The area under the curve corresponds to the proportion of time that a randomly selected BMI from the positive test group (overfat or obesity) would be larger than a randomly selected BMI from negative test group. To assess the performance of the CDC's BMI percentile screening values for overweight and obesity, ROC analysis was completed using predefined criterions for "overweight" (≥85th percentile) and "obese" (≥95th percentile).

Hierarchical regression analysis was used to describe the relationship between relative fat mass and BMI percentile at each age. Both the linear and quadratic components were tested in the models. Examination of regression model residuals indicated that a quadratic relationship would best describe the relationships.

RESULTS

Sample size, weight (BMI) status, and body composition characteristics at each age are presented in Table 1. Depending on the age, the average age-specific BMI percentile ranged from 59% to 65% for the group. At each measurement point, the BMI percentile values have the range and distribution necessary to fully assess relationships between BMI and body composition variables. Between 21% and 31% of girls were ≥85th percentile BMI-for-age and between 9% and 14% of girls were ≥95th percentile, depending on the age. These prevalence values for BMI-defined overweight and obese are similar to the age-associated prevalence values reported in the 2007-2008 National Health and Nutrition Examination Survey (9). Average relative body fatness increased with age from approximately 26% at age 9 to 28% at age 15. Between 30% and 42% of girls could be classified as "overfat" and between 17% and 29% of girls could be classified as "obese" by body fatness standards, depending on the age.

Table 2 presents the results of the ROC analysis aimed at determining the optimal BMI percentile cutoff values ("criterion") for the detection of "overfat" and "obese" girls. The criterion BMI percentile for detecting overfat and obese girls ranged from the 73rd to 81st percentile and from the 82nd to 85th percentile, respectively. The sensitivity and specificity values were generally high, with most in the 80% to 95% range. If the BMI percentile for overfat and obese is raised to the CDC's recommended BMI cutoff values for overweight and obesity (data not shown), there are more false negatives and sensitivity drops to between 0 and 76%. In contrast, specificity increases to between 96% and 100% as nearly all overfat and obese girls are correctly classified.

The Figure, which depicts the relationship between BMI percentile and relative fat mass at each measurement point,