Development of Youth Percent Body Fat Standards Using Receiver Operating Characteristic Curves

Kelly R. Laurson, PhD, Joey C. Eisenmann, PhD, Gregory J. Welk, PhD

Background: Few studies have identified health-related criterion standards of percent body fat (%BF) in U.S. youth. Further, existing standards are static thresholds (e.g., 25%, 30%) and do not account for normal growth and maturation.

Purpose: The purpose of this study was to identify thresholds of %BF in youth linked to metabolic syndrome in a large sample of U.S. children and adolescents.

Methods: Percent fat was derived from the skinfold thicknesses of those aged 12–18 years, from the National Health and Nutrition Examination Survey (NHANES [1999 –2004, N = 1966]). Metabolic syndrome was classified using previously published standards based on the National Cholesterol Education Program/Adult Treatment Panel III adult values at age 20 years. Using %BF z-scores as the test and metabolic syndrome as the criterion, receiver operating characteristic (ROC) curve analysis was used to identify %BF thresholds.

Results: ROC analysis indicated that %BF can be used with moderate accuracy to identify metabolic syndrome in adolescents. %BF thresholds of 22.3% and 35.1% in boys and 31.4% and 38.6% in girls (at age 18 years) were found to be indicative of “low” and “high” metabolic syndrome risk.

Conclusions: Age- and gender-specific %BF thresholds for creating separate risk groups were identified in relation to metabolic syndrome status. The selected thresholds identify adolescents with unfavorable metabolic profiles. These values could be extrapolated to younger children using previously created %BF centiles, which potentially allows for earlier identification and intervention of at-risk youth if tracking of current %BF was maintained. (Am J Prev Med 2011;41(4S2):S93–S99) © 2011 American Journal of Preventive Medicine

Introduction

The pediatric obesity epidemic of the past few decades has garnered considerable attention, given its widespread impact on health and well-being. Overweight or obesity in youth is typically assessed with the BMI and evaluated using age- and gender-specific percentiles from the CDC growth charts. This process is feasible, noninvasive, and accounts for normal stature and mass changes in the growing child. Furthermore, childhood overweight and obesity using these BMI thresholds is predictive of adult obesity. However, a major limitation of BMI is the lack of differentiation between fat and lean mass, which may lead to inaccurate classifications. Simple methods to assess percent body fat (%BF), such as skinfolds or bioelectrical impedance, may be needed to overcome this limitation while maintaining feasibility and validity.

In the well-known Bogalusa Heart Study, Williams et al. investigated relationships between %BF and metabolic risk using %BF intervals (e.g., 10%–14.9%, 15%–19.9%). Results indicated that skinfold-derived values of 25%BF in boys and 30%BF in girls were predictive of being in the upper quintile for systolic blood pressure (SBP), diastolic blood pressure (DBP), total cholesterol, and lipoprotein fractions. The standards provided a clear link to health outcomes and have been used previously to denote the healthy fitness zone in FITNESSGRAM® testing. A similar study by Dwyer and Blizzard, also using skinfold-derived %BF values, identified thresholds of 20%BF for boys and 30%BF for girls.
that were predictive of having higher SBP and lower high-density lipoprotein cholesterol (HDL). These thresholds were developed by subdividing %BF into the two groups that had the greatest within-group homogeneity of the risk factors.

A strength of these two studies is the use of a health outcome (e.g., blood pressure) as a criterion or end point to identify risk in children. However, a limitation of both thresholds is that they are static values (e.g., 25% for boys of all ages), designed to be used throughout childhood and adolescence. Similar to the variation in BMI during growth and maturation, body fat is known to vary naturally during development. Thus, health-related standards for body fat must take these normal developmental changes into account. The purpose of this study was to identify age- and gender-specific %BF levels corresponding with a criterion health outcome using receiver operating characteristic (ROC) curves and reference percentiles for %BF and metabolic outcomes. Although it is common to use ROC analyses to derive a single threshold value, the goal in this study was to establish multiple zones of risk that could be more useful for clinical use or as part of standardized youth fitness batteries such as FITNESSGRAM. The creation of both low-risk and high-risk thresholds would provide three zones, which would be analogous to the widely used designations of normal weight, overweight, and obese for evaluating BMI.

**Methods**

**Subjects**

Participants were from The National Health and Nutrition Examination Surveys (NHANES) conducted by the National Center for Health Statistics (NCHS) and CDC. NHANES is a program of studies created to assess the health and nutritional status of non-institutionalized adults and children in the U.S. In 1999, NHANES became a continuous survey, collecting data on approximately 5000 individuals per year, in various locations across the country. The survey combines in-home and on-site interviews with in-depth physical examinations to address a variety of health components.

In the current paper, anthropometric and metabolic data of adolescents (aged 12.0 to 18.9 years) from the first three cross-sectional waves of continuous NHANES (1999–2000, 2001–2002, and 2003–2004) were included. Complete data were available for 300 non-Hispanic white male, 275 non-Hispanic white female, 374 non-Hispanic black male, 258 non-Hispanic black female, 402 Mexican-American male, and 357 Mexican-American female adolescents aged 12–18 years (N = 1966). Individual IRB approval was not required since this analysis used only publicly available, de-identified data. However, the full NHANES protocol was reviewed and approved by the NCHS IRB, and all relevant documentation can be found online at www.cdc.gov/nchs/nhanes.htm.

**Anthropometry**

Body mass was measured using an electronic weight scale (Toledo) to the nearest 0.1 kg. Stature was measured with a wall-mounted digital stadiometer (Seca) to the nearest 0.1 cm. Subsequently, BMI was calculated by a standard formula. Waist circumference was measured just above the uppermost lateral border of the ilium at the end of a normal expiration to the nearest 0.1 cm using a steel measuring tape. Skinfold thicknesses were measured using standard procedures as a double fold of skin underlying the soft tissue on the right side of the body (Holtain calipers). The subscapular and triceps skinfolds were the only two skinfolds assessed in NHANES. All measures were completed inside the NHANES Mobile Examination Centers by trained health technicians. Quality control checks and specific protocols were used throughout the data collection process. In-depth materials, including the training procedures, examination protocol and procedures, and quality control protocol, are described in the NHANES anthropometry procedures manuals available at www.cdc.gov/nchs/nhanes.htm.

Using the triceps and subscapular skinfolds, %BF was calculated using the Slaughter equation. For boys, the regression equations factor in biological maturity status, categorizing boys as prepubescent, pubescent, or postpubescent. Since biological maturity status was not assessed in NHANES, maturity status was based on U.S. national estimates of chronologic age of entry into different stages of secondary sex characteristics. These estimates were taken from a prior release of NHANES III (1988–1994) that did assess maturity status: boys aged <12.0 years = prepubescent; boys aged 12.0–13.99 years = pubescent; and boys aged > 14.0 years = postpubescent.

**Metabolic Syndrome Variables**

Systolic and DBP were recorded as the average of three or four consecutive measurements with a mercury sphygmomanometer after the participant sat and rested quietly for 5 minutes. High-density lipoprotein cholesterol and fasting triglycerides (TG) were analyzed at the Johns Hopkins Lipoprotein Analytical Laboratory, and fasting glucose was analyzed at the University of Missouri–Columbia as detailed in the NHANES Laboratory Procedures Manuals.

Diagnosis of the metabolic syndrome was completed using age- and gender-specific youth thresholds linked to the National Cholesterol Education Program/Adult Treatment Panel III adult values. The age- and gender-specific thresholds were created via a two-step process. First, LMS (L = skewness, M = median, S = coefficient of variation) growth curves for waist circumference (WC), SBP, DBP, HDL, TG, and fasting glucose were created using adolescents from NHANES (1988–1994) and (1999–2002). The curves described the normal age-related changes in these variables from adolescence to adulthood. Second, the adult threshold for each of the metabolic variables was identified at age 20 years, and the growth centile that passed through this value was back-extrapolated into adolescence (age 12 years). The resulting thresholds are age- and gender-specific, and identify adolescents who, if they maintain their current trajectory, would be diagnosed as positive for that component of metabolic syndrome (e.g., hypertensive). These values were used to identify subjects in the current study who were above each threshold. Those with more than three
of the five metabolic components were also identified as having metabolic syndrome.

Receiver Operating Characteristics Analysis

Age- and gender-specific %BF z-scores were calculated for every adolescent using the previously created LMS percentiles. ROC curve analysis then was used to identify the %BF z-score (percentile) that was associated with a positive diagnosis for metabolic syndrome and each of the five individual components. The ROC analysis was completed separately for boys and girls. However, rather than present thresholds for each component, these ROC analyses were used only to highlight the strength of the association between each individual component and %BF. The selected %BF percentiles presented herein are those resulting from the analysis with metabolic syndrome as the outcome. It should be noted that individual ROC analyses were not completed for each age group (e.g., 12 years, 13 years), but rather as one aggregate analysis stratified by gender, resulting in percentiles specific to boys and girls. Since %BF in youth is related to age, instead of stratifying each analysis by age group and decreasing statistical power, age was incorporated into %BF (via the %BF z-score). The definition of metabolic syndrome was also age- and gender-specific. Overall, this is a more robust approach to developing consistent age- and gender-specific standards.

The complete process of ROC analysis will not be described; instead, the reader is referred to previous reviews, as well as a paper in the present supplement. In brief, ROC analysis involves the creation of a curve representing the diagnostic sensitivity (Se, true-positive rate) and specificity (Sp, true-negative rate) across a wide range of potential threshold values using the diagnostic test (in this case, %BF z-score). In these analyses, Se is equal to the probability of a metabolic syndrome–positive test value at a %BF above a threshold level in an individual who has diagnosed metabolic syndrome. Sp is equal to the probability of a metabolic syndrome–negative test value in an individual who does not have metabolic syndrome. The main goal of the analysis was to determine the threshold value where Se and Sp are maximized, indicating a threshold that maximizes the true-positive rate while maintaining a low false-positive rate.

One benefit to using ROC analysis is that each possible threshold value is evaluated and plotted in regard to Se and Sp, allowing for the selection of the threshold that best suits the desired application. For example, an emphasis could be placed on Sp so that the resulting threshold would be more conservative, thus minimizing false positives. An additional benefit to ROC analysis is the resulting area under the ROC curve (AUC). This value is used as an indicator of the global accuracy of the diagnostic test being examined, irrespective of the threshold eventually selected or the prevalence of the criterion condition. In this application, AUC relates to the ability of %BF z-scores to categorize adolescents into a group with or without metabolic syndrome (and each of the components). Like many statistics (e.g., correlation coefficients), multiple strategies exist for interpreting AUC. A commonly used set of guidelines has been provided by Swets: non-informative/equal to chance (AUC=0.5), less accurate (0.6<AUC<0.7), moderately accurate (0.7<AUC<0.9), highly accurate (0.9<AUC<1.0), and perfect discriminatory test (AUC=1.0).

Due to the NHANES complex sampling procedure, the sample design was taken into account for each statistical procedure.

Table 1. Physical characteristics of the study sample

<table>
<thead>
<tr>
<th>Characteristic, M (SE)</th>
<th>Boys (n=1076)</th>
<th>Girls (n=890)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>15.6 (0.1)</td>
<td>15.4 (0.1)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.9 (0.5)</td>
<td>161.3 (0.4)</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>66.3 (0.7)</td>
<td>57.3 (0.3)</td>
</tr>
<tr>
<td>BMI</td>
<td>22.4 (0.4)</td>
<td>21.9 (0.2)</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>19.4 (0.5)</td>
<td>26.5 (0.3)</td>
</tr>
<tr>
<td>Prevalence of risk factors, % (SE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High WC</td>
<td>8.7 (1.1)</td>
<td>19.7 (1.8)</td>
</tr>
<tr>
<td>High BP</td>
<td>10.0 (1.3)</td>
<td>3.2 (1.0)</td>
</tr>
<tr>
<td>High TG</td>
<td>13.5 (2.0)</td>
<td>10.0 (2.0)</td>
</tr>
<tr>
<td>Low HDL-C</td>
<td>28.7 (2.3)</td>
<td>41.1 (2.2)</td>
</tr>
<tr>
<td>High fasting glucose</td>
<td>11.4 (1.7)</td>
<td>4.3 (0.8)</td>
</tr>
<tr>
<td>Metabolic syndrome</td>
<td>5.5 (1.3)</td>
<td>3.4 (1.0)</td>
</tr>
</tbody>
</table>

Note: Body fat estimated by triceps and subscapular skinfolds using Slaughter et al. equations. Thresholds for each individual metabolic syndrome component presented in Jolliffe and Janssen.

Subjects with ≥3 individual components were identified as having metabolic syndrome.

BP, blood pressure; HDL-C, high-density lipoprotein cholesterol; TG, triglycerides; WC, waist circumference

The sampling weights, strata, and clusters were used throughout. All analyses were conducted using SAS v 9.1. The ROC analyses performed here employed a macro program provided by Dr. Mithat Gönen (Memorial Sloan-Kettering Cancer Center, personal communication, 2008). The purpose of the macro was to apply the NHANES sample weights to the data and subsequently calculate ROC statistics (such as Se and Sp) for each possible threshold of %BF z-score. After using this information to select the most appropriate threshold, dichotomies were created in the data set to classify subjects into high and low %BF groups. Finally, Proc SurveyFreq (SAS) was used in conjunction with the survey sample weights, strata, and clusters to calculate 95% CIs.

Results

Descriptive statistics and the prevalence of metabolic syndrome and its components are shown in Table 1. Compared to national growth charts, mean stature for boys and girls approximated the 50th percentile, whereas mean body mass and BMI approximated the 75th percentile for both genders. The prevalence of the components of metabolic syndrome varies between the genders, and the resulting prevalence of metabolic syndrome is 5.5% and 3.4% in boys and girls, respectively.

The AUC values from the analyses using %BF z-score to differentiate between youth positive and negative for the components of metabolic syndrome are shown in

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Table 2. Performance of percent body fat z-score as a global diagnostic indicator of metabolic syndrome and its individual components in adolescents

<table>
<thead>
<tr>
<th>Metabolic component</th>
<th>AUC</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td></td>
</tr>
<tr>
<td>Metabolic syndrome</td>
<td>0.885</td>
<td>0.836</td>
<td></td>
</tr>
<tr>
<td>Waist circumference</td>
<td>0.956</td>
<td>0.919</td>
<td></td>
</tr>
<tr>
<td>Blood pressure</td>
<td>0.638</td>
<td>0.646</td>
<td></td>
</tr>
<tr>
<td>Triglycerides</td>
<td>0.737</td>
<td>0.642</td>
<td></td>
</tr>
<tr>
<td>High-density lipoproteins</td>
<td>0.669</td>
<td>0.616</td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>0.560</td>
<td>0.518</td>
<td></td>
</tr>
</tbody>
</table>

Note: Significant AUCs are in bold. Values represent AUC for receiver operating characteristics. AUC, area under the curve

The ROC analysis indicated that the 85th and 68th %BF percentiles for boys and girls, respectively, best differentiate between those with and without metabolic syndrome in the current sample (determined by maximizing the sum of Se and Sp – 1). For girls, the 68th percentile had a high Se (≥90), and it was already the optimal value identified from the ROC curve. However, the 85th percentile in boys had a Se=83.3 and Sp=86.4. The threshold with the highest sum of Se and Sp, the 69th percentile, was selected as the low-risk threshold. This was done to provide a threshold with a Se≥90. For the high-risk threshold, a threshold with a Sp≥90 that still maintained the highest possible Se in the sample was selected. Table 3 summarizes the selected thresholds from the ROC analysis using %BF z-scores and provides the age- and gender-specific %BF values.

Discussion

This study identified age- and gender-specific %BF thresholds that are linked to a criterion health outcome, metabolic syndrome. Both the use of %BF z-scores and the pediatric definition of metabolic syndrome take into consideration the changes in adolescence due to growth and maturation. Although using longitudinal data would be ideal to account for such changes, the current cross-sectional analysis can serve as a starting point for early identification of at-risk youth.

The AUC values for the metabolic syndrome ROC analyses (0.885 and 0.836 for boys and girls, respectively) indicate that %BF z-scores have moderate diagnostic capabilities to identify adolescents with metabolic syn-

Table 3. Percent body fat thresholds, percentiles, and corresponding sensitivity and specificity in youth

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th></th>
<th></th>
<th>Girls</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Low-risk</td>
<td>High-risk</td>
<td></td>
<td>Low-risk</td>
<td>High-risk</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.0–12.9</td>
<td>23.7</td>
<td>35.9</td>
<td></td>
<td>26.8</td>
<td>35.5</td>
<td></td>
</tr>
<tr>
<td>13.0–13.9</td>
<td>22.9</td>
<td>35.0</td>
<td></td>
<td>27.8</td>
<td>36.3</td>
<td></td>
</tr>
<tr>
<td>14.0–14.9</td>
<td>21.4</td>
<td>33.2</td>
<td></td>
<td>28.6</td>
<td>36.8</td>
<td></td>
</tr>
<tr>
<td>15.0–15.9</td>
<td>20.2</td>
<td>31.5</td>
<td></td>
<td>29.2</td>
<td>37.1</td>
<td></td>
</tr>
<tr>
<td>16.0–16.9</td>
<td>20.2</td>
<td>31.6</td>
<td></td>
<td>29.8</td>
<td>37.4</td>
<td></td>
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<tr>
<td>17.0–17.9</td>
<td>21.0</td>
<td>33.0</td>
<td></td>
<td>30.5</td>
<td>37.9</td>
<td></td>
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<tr>
<td>18.0–18.9</td>
<td>22.3</td>
<td>35.1</td>
<td></td>
<td>31.4</td>
<td>38.6</td>
<td></td>
</tr>
<tr>
<td>%BF percentile</td>
<td>69th</td>
<td>90th</td>
<td></td>
<td>68th</td>
<td>90th</td>
<td></td>
</tr>
<tr>
<td>Sensitivity (95% CI)</td>
<td>95.0 (87.1, 100.0)</td>
<td>73.4 (47.7, 91.1)</td>
<td>96.8 (91.7, 100.0)</td>
<td>39.9 (16.7, 63.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specificity (95% CI)</td>
<td>71.0 (66.3, 75.6)</td>
<td>90.2 (87.8, 92.5)</td>
<td>68.9 (65.2, 72.7)</td>
<td>90.7 (87.9, 93.4)</td>
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</tbody>
</table>

%BF, percent body fat
drome. For example, a randomly selected subject from the metabolic syndrome positive sample has a %BF higher than that of a randomly selected subject from the metabolic syndrome–negative sample 88.5% and 83.6% of the time in boys and girls, respectively. It is important to note that the AUC values were larger for metabolic syndrome than for the individual components of the metabolic syndrome with the exception of WC. This indicates that %BF has a lower accuracy when identifying adolescents with single risk factors, but performs better when multiple (≥3) risk factors are clustered within subjects. This result is encouraging, considering that multiple factors, independent of %BF, such as family history, diet, physical activity, and aerobic fitness, are also associated with the development of metabolic syndrome in youth.22–24

To our knowledge, few studies have used metabolic syndrome as the criterion to identify corresponding healthy ranges of %BF. Using NHANES III (1988–1994) data in adults, Zhu et al.25 used logistic regression to identify %BF thresholds that corresponded to equivalent risk of metabolic syndrome at the established adult BMI thresholds of 25, 30, and 35. Results were presented separately for whites and blacks, but the differences in identified %BF cut-offs were small. They identified (approximated) %BF thresholds of 21.5%, 28.7%, and 36.0% in men and 31.4%, 37.2%, and 42.8% in women, respectively. Although their data were based on metabolic syndrome diagnosis in adults, rather than adolescents, the results are comparable.

The current study identifies thresholds (at age 18.0–18.9 years) of 22.3% and 35.1% in boys, which approximate the cutoffs for BMI of 25 and 35 kg/m² in the adult study.25 In girls, the identified thresholds of 31.4% and 38.6% correspond to the cut-offs for BMI of 25 and 30 kg/m² in the adult study. In general, it appears that perhaps the girls’ threshold in the current paper could be adjusted to a higher percentile to allow it to more closely align to the threshold of 35 of the Zhu et al. study (instead of 30). Increasing the %BF values for the high-risk group is an option, if desired. However, if this percentile were increased, Se would be reduced to a greater degree, and more false negatives would result. Despite this fact, there is relatively good agreement between the two studies, considering the differences in methodology. Although the approach of Zhu et al. incorporated BMI to define healthy %BF standards, rather than %BF alone, the odds of metabolic syndrome drastically escalate as adult BMI increases above 25 and 30.26 These data provide evidence supporting the maintenance of a healthy adiposity level and risk of metabolic syndrome in both adolescents and adults.

In regard to the individual components of metabolic syndrome, %BF z-scores had varying diagnostic capabilities (AUC range = 0.518 to 0.956). Evaluating diagnostic accuracy using AUC, %BF was highly accurate at detecting elevated WC, although this is to be expected since both are assessments of adiposity and are generally highly correlated. This could indicate that WC alone could be used to identify youth at risk of metabolic syndrome, which is intuitive since WC is an integral component of the syndrome. However, although BP, TG, and HDL were not as strongly associated with %BF, AUC values ranged from moderate to less accurate, and results using %BF to detect a clustering of risk factors as metabolic syndrome were encouraging. This is in agreement with the findings of Williams et al.,5 who found that increasing levels of %BF were associated with blood pressure and lipoprotein ratios in a biracial sample of children and adolescents. Also, Dwyer and Blizzard7 found %BF predictive of SBP and HDL when evaluated in those aged 9–15 years.

The lowest AUC value was for fasting glucose. This finding could be related to fasting blood glucose being normal in overweight youth.27 In contrast, fasting insulin and glucose utilization are found to be significantly associated with %BF.28 Likewise, Panagopoulou et al.29 showed no significant difference in fasting glucose between obese and lean youth, although the obese sample had significantly higher means for homeostatic model assessment for insulin sensitivity (HOMA) and fasting insulin. Similarily, Ruiz et al.30 found that fasting glucose was not associated with adiposity, whereas both HOMA and insulin showed significant associations. Hence, it appears that %BF may be more closely related to other measures of impaired carbohydrate metabolism, such as HOMA, rather than fasting glucose, in children and adolescents. This is likely due to insulin resistance preceding impaired glucose tolerance.31 Future research should consider incorporating an assessment of insulin resistance when investigating a healthy %BF range in youth, since this may further improve diagnostic utility.

One limitation of the current study is the cross-sectional analysis. Ideally, %BF thresholds would be determined in a prospective cohort with youth %BF values predicting adult health outcomes. Although use of the reference percentiles and z-scores in these analyses serve as a proxy for potential differences due to maturation, they are not a substitute for longitudinal analyses that incorporate maturity assessment. Another possible limitation is the definition of metabolic syndrome used as the criterion. However, there is no widely accepted definition of pediatric metabolic syn-
drome. In a review by Ford and Li, 40 different definitions of metabolic syndrome were identified in previous studies, with the modified National Cholesterol Education Program/Adult Treatment Panel III thresholds being the most widely used.

The Jolliffe and Janssen growth curve definition of metabolic syndrome was especially appropriate in the current study, as a large portion of the NHANES subjects in the current analysis overlapped with their sample (NHANES [1999–2002]). Additionally, there is a considerable difference in the gender-specific prevalence for some of the individual metabolic syndrome components (Table 1). The estimated prevalence will largely depend on the definition of metabolic syndrome selected. Prevalence may also be affected as a result of differential timing and progression of puberty for boys and girls in this age range. Although this limitation is important and should be considered here and in future research, it should also be noted that the AUC for the individual risk factors are similar (Table 2). This indicates that the age- and gender-specific relationships between %BF and many of the components are similar, regardless of prevalence.

Other limitations include potential error in the estimation of %BF from skinfolds and the assumption of pubertal status in boys based on chronologic age. Further, it is reasonable to suspect that ethnic variation exists in the relationship between adiposity and metabolic syndrome. Ethnicity-specific standards may enhance the accuracy of such %BF thresholds. This is an important issue, and hopefully future research can evaluate the magnitude of this variable and overcome this potential limitation. However, FITNESSGRAM has never employed ethnicity-specific standards, and maintaining the simplicity of prior releases of FITNESSGRAM was important for individuals eventually using these standards, such as teachers, administrators, parents, and students. Therefore, only age- and gender-specific standards are presented.

There are several strengths of the current study, including the use of a large, nationally representative sample of adolescents, the incorporation of reference percentiles in an attempt to summarize age- and gender-specific differences (for both %BF and the definition of metabolic syndrome), and the use of ROC curves to evaluate the performance of multiple thresholds in creating differing levels of risk.

In summary, %BF can be used with moderate accuracy to differentiate between adolescents with and without metabolic syndrome. By using ROC curve analyses, the Se and Sp of multiple thresholds was evaluated, allowing for an objective determination of the performance of %BF thresholds to identify adolescents with unfavorable metabolic profiles. Age- and gender-specific %BF thresholds for creating separate risk groups were identified using nationally representative growth percentiles. The current study used adolescents (aged 12–19 years) to derive %BF standards. However, these values could be extrapolated to younger children using the previously created %BF centiles, which potentially allows for earlier identification and intervention of at-risk youth if tracking of current %BF was maintained.

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