

## [ Primary Care ]

# Body Mass Index and Percentage of Body Fat as Indicators for Obesity in an Adolescent Athletic Population

William C. Etchison, MS\*, Elizabeth A. Bloodgood, MS, PT, ATC†, Cholly P. Minton, BA‡, Nancy J. Thompson, PhD, MPH§, Mary Ann Collins, BS,¶, Stephen C. Hunter, MD\*\*†, and Hongying Dai, PhD†

**Background:** Body mass index (BMI) is widely accepted in determining obesity. Skinfold thickness measurements have been commonly used to determine percentage of body fat.

**Hypothesis:** The authors hypothesize that because BMI does not measure fat directly but relies on body weight alone, a large percentage of athletic adolescents will be misclassified as obese by BMI.

**Design:** Cross-sectional study.

**Methods:** To compare BMI and skinfold measurements as indicators for obesity in the adolescent athletic population, anthropometric data (height, weight, percentage body fat, age, and sex) were recorded from 33 896 student athletes (average age, 15 years; range, 11-19 years) during preparticipation physical examinations from 1985 to 2003. BMI was calculated from height and weight. Percentage of body fat was determined by measuring skinfold thickness.

**Results:** According to their BMI percentile, 13.31% of adolescent athletes were obese. Using the skinfold method, only 5.95% were obese. Of those classified as obese by the BMI, 62% were considered false positives by the skinfold method. In contrast, there was a 99% probability that the nonobese by BMI would not be obese by the skinfold method (negative predictive value = 0.99).

**Conclusions:** BMI is a measurement of relative body weight, not body composition. Because lean mass weighs far more than fat, many adolescent athletes are incorrectly classified as obese based on BMI. Skinfold testing provides a more accurate body assessment than BMI in adolescent athletes.

**Clinical Relevance:** Correct body composition data can help to provide better diet and activity guidelines and prevent the psychological problems associated with being labeled as obese.

**Keywords:** body mass index; skinfold; adolescent; obesity

Body mass index (BMI) is widely used to define obesity in the adolescent population. In May 2000, the Centers for Disease Control and Prevention revised its growth charts and added the use of BMI by age and sex to help identify growth weight patterns. The centers identified the 85th percentile line as “at risk for overweight” and the 95th percentile as “obese.”<sup>6</sup> In 2003, the American Academy of Pediatrics issued a policy statement supporting the use of BMI in tracking growth patterns and identifying the overweight

and obese individual.<sup>1,2</sup> In 2007, the US Department of Health and Human Services updated its position on preventing obesity, citing the use of BMI to help track and prevent obesity while recognizing the relationship between obesity and poor self-esteem and psychosocial problems.<sup>18</sup> Weight loss is recommended for anyone in the 85th percentile of BMI or higher.<sup>7</sup>

Very few investigators have looked at the body composition of adolescent athletes.<sup>8,17</sup> A few studies analyzed body

From the The Hughston Clinic, Columbus, Georgia, †Lanier Health Services, Lanett, AL, ‡The Hughston Foundation, Columbus, GA, and §Emory University, Atlanta, GA

¶Deceased, \*Children's Mercy Hospital Kansas City, MO.

\*William C. Etchison, MS, The Hughston Clinic, 6262 Veterans Parkway, Columbus, GA 31908; Phone (706) 324-6661; Fax (706) 494-3247 (e-mail: betchison@hughston.com)

DOI: 10.1177/1941738111404655

© 2011 The Author(s)

composition of college and elite athletes.<sup>10,13,19,21</sup> These studies support the use of skinfold testing as a simple and reliable test to determine body fat. Because BMI utilizes only body weight and height and does not take into account overall body composition, including body fat, muscular individuals may be classified as obese.<sup>20</sup> Consequently, even though it is widely accepted, BMI may actually be a poor indicator for obesity in the adolescent athletic population.

## MATERIALS AND METHODS

Anthropometric data for 33 896 student athletes were collected between 1985 and 2003 at semiannual preparticipation screenings for school athletes in Georgia and Alabama. In the state in which the screenings took place, medical clearance is required before participation in any school-sanctioned sports team or group. Before the screening, a signed release was required by parents or legal guardian or by the athlete if he or she was 18 years of age or older. Data collected included age, race, sex, height, weight, sport, medical history, percentage body fat, and blood pressure. Orthopaedic and general medical screening and agility testing were also part of the physical examination. A licensed physician reviewed all data and a *pass*, *conditional pass*, or *fail* status was assigned to the screening. Approval to use the data for this study was granted by an institutional review board.

The examinations were conducted twice per year, with 51% of students screened in the winter-spring semesters and with 49% of students screened in the fall semesters. Each year, an average of 1888 students was evaluated. Students were between 11 and 19 years old, with a majority (88%) between 14 and 17 years of age. The average age of the athlete was  $15.24 \pm 0.01$  years.

Professional physician-grade scales were used to collect weight data, and height without shoes was recorded using a standard measure against the wall. Trained personnel recorded height and weight. For the purpose of this study, weight measures were converted from pounds to kilograms and height measures from inches to meters. BMI was calculated for all athletes using the formula of  $\text{kg}/\text{m}^2$ . Each athlete was then classified as obese or not obese according to BMI using the BMI-for-age percentiles charts developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion.<sup>5</sup> Athletes with a calculated BMI of greater than or equal to the 95th percentile for their adjusted age and sex were classified as obese.

Percentage of body fat was determined by skinfold thickness measurements taken with the Skyndex/System I caliper (Caldwell, Justiss & Co, Inc, Fayetteville, Arkansas). The Skyndex Electronic Body Fat Calculator was programmed with the Jackson-Pollock formula, which uses formulae developed and widely accepted by Jackson and Pollock for men<sup>11</sup> and by Jackson, Pollock, and Ward for women.<sup>12</sup> Following the guidelines of the standardized skinfold technique, 3 points of measurement were taken: at the lateral border of the pectoralis

Table 1. Kappa coefficient guide.

$\kappa$	Strength of Agreement
0.00	No/poor
0.01-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost perfect

major muscle, at the abdomen vertically along the side of the umbilicus, and at the anterior midhigh in male participants. In female participants, measurements were taken at the triceps, vertically midway between the shoulder and the elbow, at the iliac crest measured at a 45° angle directly on top of the crest of the hip in line with the axilla, and at the anterior midhigh.<sup>16</sup> Male participants with a percentage body fat of 24% or greater and female participants with a percentage body fat of 30% or greater were classified as obese according to the Skyndex manual recommendations.<sup>16</sup> All skinfold thickness testing was performed by trained health care professionals—either athletic trainers or exercise physiologists—and directly supervised by the senior author, who performed the majority of the skinfold testing.

## STATISTICAL ANALYSIS

Statistical analysis was performed using SAS 8 software (SAS Institute, Inc, Cary, North Carolina). Pearson  $\chi^2$  test, Fisher exact test, logistic regression, and simple and multiple linear regressions were used with 5% significance level. McNemar test and the  $\kappa$  coefficient (Table 1) were determined to compare the 2 testing procedures. McNemar test was used to detect differences in the proportions of obesity according to the percentile of BMI and the percentage of body fat. The  $\kappa$  coefficient was used to determine the agreement between the 2 obesity evaluation approaches.

## RESULTS

Of the 33 896 student athletes assessed, 301 had incomplete data sets and were excluded, leaving 33 595 student athletes for the statistical analysis (Table 2). Of these student athletes, 65.4% were male, 34.6% female, 55.6% black, 42.0% white, and 2.4% other. Overall, 88.5% of students passed, 11.3% passed conditionally, and 0.16% failed the preparticipation evaluation.

McNemar test was used to detect differences in the proportions of obesity according to the percentile of BMI and the percentage of body fat, respectively. The result of McNemar test ( $P < 0.01$ ) indicated that the proportions of obesity under the 2 rating criteria are significantly different (Table 3).

Table 2. Study participants (n = 33 595).

Characteristic	Value
Height, in (cm)	65.06 ± 0.02 (165.25 ± 0.05)
Weight, lb (kg)	147.27 ± 0.19 (66.80 ± 0.09)
Body mass index	22.88 ± 0.02
Body fat, %	14.59 ± 0.04
Obese athletes, n (%)	
By body mass index	4470 (13.31)
By skinfold	1999 (5.95)

Table 3. Comparison of proportions of obesity under body mass index and body fat assessments at different ages.

Age, y	n	Obesity Proportion, %		P
		Body Fat	Body Mass Index	
11	123	13.01	26.02	< 0.0001
12	825	10.06	20.00	< 0.0001
13	2105	6.98	14.87	< 0.0001
14	7251	5.90	12.41	< 0.0001
15	8778	5.79	12.87	< 0.0001
16	7751	5.92	13.77	< 0.0001
17	5677	5.28	12.47	< 0.0001
18	1036	5.50	14.38	< 0.0001
19	49	2.04	12.24	0.0253

The  $\kappa$  coefficient was determined to measure the agreement between the 2 obesity evaluation approaches (Table 4). In 9% of participants (3061 of 33 595), BMI and body fat criteria resulted in discordant obesity status. Kappa coefficient was 0.4844 (95% confidence interval, 0.4692-0.4996), suggesting only moderate agreement between the 2 assessments.

The sensitivity results demonstrated that 85% (1704 of 1999) of those classified as obese by their measured body fat were also classified as obese by their BMI (sensitivity = 0.85). Specificity demonstrated that 91% (28 830 of 31 596) of those not classified as obese by their measured body fat were also not considered obese by their BMI (specificity = 0.91). Only 38% (1704 of 4470) of those classified as obese by BMI were also classified as obese by their body fat (positive predictive value = 0.38). The remaining 62% (2766 of 4470) of those classified as obese by BMI were false positives; they were not

classified as obese by their body fat. In contrast, there was a 99% probability that those who were not classified obese by their BMI would not be considered obese by their body fat (negative predictive value = 0.99). Thus, only 1% (295 of 29 125) of those not classified as obese by their BMI were considered to be obese according to their body fat.

## DISCUSSION

The purpose in conducting this study was to examine the relationship between BMI and percentage of body fat in the adolescent athlete. BMI is the current standard in determining obesity in the adolescent population. These results suggest that if the child is an athlete, percentage of body fat should be assessed with the annual BMI recommendation of the American Academy of Pediatrics.<sup>1</sup> BMI is more likely than percentage of body fat to rate a student athlete as obese. Sixty-two percent of those identified as obese with BMI were not found to be obese with the percentage of body fat. Only 1% of those classified as obese with percentage of body fat were not considered obese by BMI standards. These results suggest that the percentage body fat measurement is statistically more accurate than BMI in defining obesity in the adolescent athlete.

The American Academy of Pediatrics Policy statement cautions that when using BMI, “clinical judgment must be used in applying these criteria to a patient because obesity refers to excess adiposity rather than excess weight, and BMI is a surrogate for adiposity.”<sup>2</sup> In December 2005, the American Academy of Pediatrics issued a policy statement on the promotion of healthy weight control in young athletes. It cautioned against the sole use of BMI, recommending other anthropometric measurements to augment BMI results.<sup>3</sup> In 2005, Witt and Bush<sup>21</sup> studied college athletes and concluded that “BMI frequently classified muscular individuals who did not have high skinfold measurements as overweight.” In 2007, Ode et al<sup>14</sup> suggested, “BMI should be used cautiously when classifying fatness in college athletes and non-athletes,” favoring the development of different BMI overweight categories in these specific populations.

The triceps skinfold may be the best screening tool for adolescents 10 to 15 years of age.<sup>15</sup> In female college athletes, skinfold measurements taken at the abdomen and thigh were the best predictors of body fat compared with BMI and dual energy x-ray absorptiometry.<sup>19</sup>

In 986 children aged 8 to 12 years, skinfold measurement was the best determinant of adiposity in the child.<sup>4</sup> Hortobágyi et al<sup>9</sup> also concluded that the skinfold method was recommended for a quick and accurate assessment of body composition and fat in the college football athletic population.

As with any large population study, there are limitations. This study took place over several years with a variety of health care professionals performing the skinfold measurements. Most measurements were taken by the senior author, and the remainder was done with his supervision. Additionally, the reproducibility of skinfold measurements was not tested. Highly accurate measurements of body composition and the

Table 4. Agreement between body mass index and body fat assessments at different ages.

Age, y	Sensitivity	Specificity	Predictive Value		$\kappa$ (95% Confidence Interval)	Agreement
			Positive	Negative		
11	1.0000	0.8505	0.5000	1.0000	0.5967 (0.4281, 0.7654)	Moderate
12	0.9277	0.8814	0.4667	0.9909	0.5624 (0.4865, 0.6382)	Moderate
13	0.8639	0.9050	0.4058	0.9888	0.5051 (0.4483, 0.562)	Moderate
14	0.8435	0.9210	0.4011	0.9895	0.5040 (0.4706, 0.5374)	Moderate
15	0.8445	0.9152	0.3796	0.9897	0.4825 (0.4523, 0.5127)	Moderate
16	0.8627	0.9080	0.3711	0.9906	0.4756 (0.4443, 0.5068)	Moderate
17	0.8300	0.9146	0.3517	0.9897	0.4535 (0.4148, 0.4921)	Moderate
18	0.8421	0.8968	0.3221	0.9899	0.4198 (0.3345, 0.5052)	Moderate
19	1.0000	0.8958	0.1667	1.0000	0.2598 (-0.1536, 0.6732)	Fair

Careful definition of obesity are extremely important because of the adverse consequences in adulthood. These results support the use of percentage of body fat over BMI when determining the body composition of the adolescent athletic population.

## REFERENCES

- American Academy of Pediatrics. AAP guidelines on childhood obesity. *Am Fam Physician*. 2003;68(7). <http://www.aafp.org/afp/20031001/clinical.html>. Accessed May 15, 2007.
- American Academy of Pediatrics. Committee on Nutrition. Prevention of pediatric overweight and obesity. *Pediatrics*. 2003;112(2):424-430.
- American Academy of Pediatrics. Committee on Sports Medicine and Fitness. Promotion of healthy weight-control practices in young athletes. *Pediatrics*. 2005;116(6):1557-1564.
- Bedogni G, Lughetti L, Ferrari M, et al. Sensitivity and specificity of body mass index and skinfold thicknesses in detecting excess adiposity in children aged 8-12 years. *Ann Hum Biol*. 2003;30(2):132-139.
- Centers for Disease Control and Prevention. Growth charts. <http://www.cdc.gov/growthcharts>. Published May 2000. Modified October 2000.
- Dawson P. Practice guidelines; revised growth charts for children. *Am Fam Physician*. 2002;65(9):1941-1942.
- Fowler-Brown A, Kahwati LC. Prevention and treatment of overweight in children and adolescents. *Am Fam Physician*. 2004;69:2591-2598.
- Hergenroeder AC, Klish WJ. Body composition in adolescent athletes. *Pediatr Clin North Am*. 1990;37(5):1057-1083.
- Hortobágyi T, Israel RG, Houmard JA, O'Brien KF, Johns RA, Wells JM. Comparison of four methods to assess body composition in black and white athletes. *Int J Sport Nutr*. 1992;2(1):60-74.
- Houtkooper LB, Mullins VA, Going SB, Brown CH, Lohman TG. Body composition profiles of elite American heptathletes. *Int J Sport Nutr Exerc Metab*. 2001;11(2):162-173.
- Jackson AS, Pollock ML. Generalized equations for predicting body density of men. 1978. *Br J Nutr*. 2004;91(1):161-168.
- Jackson AS, Pollock ML, Ward A. Generalized equations for predicting body density of women. *Med Sci Sports Exerc*. 1980;12(3):175-182.
- Nevill AM, Stewart AD, Olds T, Holder R. Relationship between adiposity and body size reveals limitations of BMI. *Am J Phys Anthropol*. 2006;129(1):151-156.
- Ode JJ, Pivamik JM, Reeves MJ, Knous JL. Body mass index as a predictor of percent fat in college athletes and nonathletes. *Med Sci Sports Exerc*. 2007;39(3):403-409.
- Sardinha LB, Going SB, Teixeira PJ, Lohman TG. Receiver operating characteristic analysis of body mass index, triceps skinfold thickness, and arm girth for obesity screening in children and adolescents. *Am J Clin Nutr*. 1999;70(6):1090-1095.
- Skyndex I Instruction Manual*. Fayetteville, AR: Caldwell, Justiss & Co Inc.
- Sport Medicine and Science Council of Saskatchewan. Guidelines for skinfold testing in young athletes. <http://www.usask.ca/sportmedsci/nutr/skinfoldguidelines.htm>. Accessed August 16, 2010.
- US Department of Health and Human Services. The problem of overweight in children and adolescents: the surgeon general's call to action to prevent and decrease overweight and obesity. [http://www.surgeongeneral.gov/topics/obesity/calltoaction/fact\\_adolescents.htm](http://www.surgeongeneral.gov/topics/obesity/calltoaction/fact_adolescents.htm). Accessed July 17, 2007.
- Warner ER, Fornetti WC, Jallo JJ, Pivarnik JM. A skinfold model to predict fat-free mass in female athletes. *J Athl Train*. 2004;39(3):259-262.
- Whitlock EP, Williams SB, Gold R, Smith PR, Shipman SA. Screening and interventions for childhood overweight: a summary of evidence for the US Preventive Services Task Force. *Pediatrics*. 2005;116(1):125-144.
- Witt KA, Bush EA. College athletes with an elevated body mass index often have a high upper arm muscle area, but not elevated triceps and subscapular skinfolds. *J Am Diet Assoc*. 2005;105(4):599-602.

For reprints and permission queries, please visit SAGE's Web site at <http://www.sagepub.com/journalsPermissions.nav>.