Assessment and Interpretation of Body Composition in Physical Education

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Should you use skinfolds, bio-electrical impedence, or BMI?

The physical educator's role is evolving into that of a teacher who is well educated in the areas of teaching, skill acquisition and development, motor learning, exercise physiology, physical conditioning, weight management, health, and lifestyle management. In an era when childhood obesity is at an all-time high, body composition assessments are an important component of a physical education curriculum that is centered on the development of skills, lifetime physical activity, and health behaviors. In a well-rounded physical education program, assessment of body composition can be one component of a complete fitness appraisal, included in a unit on physical fitness or physical activity and health, or it can be an informational booth at a school's health fair. A physical educator can also assess the body composition of boys and girls on an athletic team that they coach. In any case, physical educators must be able to accurately assess body composition in children and adolescents, interpret the results correctly, discuss the results in an appropriate manner with students, and conduct meaningful research. The purpose of this article is to provide relevant background information about body composition and its assessment as well as the interpretation of results in an appropriate context for physical educators. Table 1 provides definitions of a number of terms used in this article.

Models of Body Composition

The majority of body fat is stored in fat cells (adipocytes) beneath the skin (subcutaneous fat) and around the organs (visceral fat). A smaller amount of fat is stored in most, if not all, other cells in the body. Some fat (3-5% in males; 8-12% in females) is essential to normal bodily functions, such as the fat that is part of the nervous system or surrounding visceral organs in females (Kaminsky & Dwyer, 2006). Subcutaneous and visceral fat also serve important functions, but an excess increases the risk of cardiovascular disease, type 2 diabetes, hypertension, hyperlipidemia, metabolic syndrome, coronary artery disease, and certain types of cancer.

There are several models of body composition (Wang, Heshka, Pierson, & Heymsfield, 1995; Wang, Pierson, & Heymsfield, 1992), which divide the weight of the body into components. Models of the body's composition form the basis for body composition assessments, which estimate one or more of the components of the model. Physical educators typically use methods of body composition assessment that compartmentalize the body into two components, the fat mass (FM) and fat-free mass (FFM).

Classification of Methods

Methods of assessing body composition in live humans generally can be referred to as criterion or prediction methods, or as laboratory or field methods. A criterion method is thought to be one of the most accurate ways of assessing body composition, and therefore is often called the "gold standard." Historically, hydrodensitometry (underwater weighing) has been the gold standard. In recent years, air displacement plethysmography (Bod Pod) and dual energy x-ray absorptiometry (DEXA) have emerged as accepted gold standards. When doing research to determine how accurate a method is in predicting percent body fat (%BF), the body composition of each subject is assessed using two methods, a criterion method and a prediction method. For example, research might result in the development of an equation using skinfold measurements to predict the %BF value obtained from hydrodensitometry in a group of children and adolescents. Other research may use the previously derived skinfold equation to predict the %BF value obtained from hydrodensitometry in a group of students of different ages, gender, or ethnicity. In both of these examples, hydrodensitometry is the criterion method and skinfolds is the prediction method. These two terms are most often used to describe research methods. In reality, all methods predict %BF in live humans since the true amount of body fat is unknown.

Methods of assessing body composition can also be categorized as either laboratory or field methods. Methods such as hydrodensitometry, Bod Pod, and DEXA are often restricted for use in laboratory settings due to cost, size, portability, and use of technology. Two methods often used in physical education settings, bio-electrical impedance (BIA) and skinfolds, are considered field methods because they are less time- and labor-intensive, less expensive, and easily portable. Laboratory methods are often used as criterion methods in research.

Validity and Reliability

There will always be some error in every assessment of %BF because no method actually measures body fat and no method makes perfect predictions. Error may originate from the failure to follow correct procedures, use of equipment that is not calibrated, subjects not complying with testing procedures, or error inherent in the prediction equation. Error affects the validity and reliability of a method. Physical educators may refer to other sources (Berg & Latin, 2004; Morrow, Jackson, Disch, & Mood, 2005) for a thorough review of the expression of validity and reliability. A brief summary is included here for the purpose of elucidating other content of this article.

Validity is defined as the ability of a method to accurately predict body composition compared to a criterion method. Validity should be determined in a sample of people similar in age, gender, and ethnicity to the students that will be tested. Reliability is defined as the ability of the method to predict %BF consistently between several trials on the same day (trial-to-trial reliability) or between days (day-to-day reliability). A method can be reliable but not valid. For example, a method may consistently predict a student's %BF to be 25% when in actuality the student's body composition is thought to be 15% fat. A method that is not reliable cannot be valid. For example, a method which produces inconsistent results cannot be valid since there would be uncertainty as to which value is correct.

Although there are several ways to express the accuracy of a prediction, the standard error of estimate (SEE) is the most common. The SEE is a research-based statistic that describes the amount of variability (error) in a prediction. Using the bell-shaped curve for normal distribution, 68% and 95% of the individuals with the same predicted value will have a %BF determined from the criterion method within ±1 SEE and ±2 SEE of the predicted value, respectively. For example, if the %BF of 100 students was predicted by measuring skinfold thickness (SEE = ±3.5% BF), then 68 of those students will have a predicted %BF ± 3.5% body fat away from the criterion value and 95 of those students would have a predicted %BF ± 7.0% body fat away from the criterion value. This further implies that the remaining 5 of the 100 students (5%) will have a prediction %BF value that exceeds ±7.0% body fat of the criterion value. The lower the SEE, the more confident one can be that a predicted %BF is close to the criterion value, whereas the higher the SEE, the less confident one can be that a prediction score is accurate.

Table 1. Definitions

- *Anthropometrics.* The measurement of physical dimensions of the body such as height, weight, skinfold thickness, and circumferences.
- *Body composition.* The partitioning of the body into components such as fat mass, fat-free mass, lean body mass, bone, total body water, minerals, and proteins. Most often expressed as percent body fat.
- *Body mass index (BMI).* The ratio of body weight (in kilograms) divided by body height (in meters squared) expressed in unit values of kg/m^2. Used to determine the degree of obesity.
- *Essential body fat.* The minimal amount of fat necessary for normal body functions. Usually represents about 3-5% of body weight in males and 8-12% of body weight in females.
- *Fat mass (FM).* The total amount (in kilograms) of stored fat, including essential fat. Calculated by multiplying total body weight by percent body fat.
- *Fat-free mass (FFM).* The portion of total body weight that is water, protein, or bone mineral and does not contain any fat. Estimated by subtracting FM from the total body weight.
- *Gold standard.* A criterion method of assessing body composition to which other methods are compared.
- *Lean body mass.* The FFM plus essential body fat.
- *Percent body fat.* The percentage of one's body weight that is fat mass.
- *Total body water.* The total amount of intra- and extra-cellular water (in liters) in the body.

Methods of Assessing Body Composition

There are no direct measures of body composition. All methods used to "measure" body composition actually predict %BF. As already noted, there are several "gold standard" methods of assessing body composition. Although a

Figure 1. Various Skinfold Calipers

Fat Control (A), Fat-O-Meter (B), SlimGuide (C), Lange (D), and Harpenden (E) skinfold calipers.

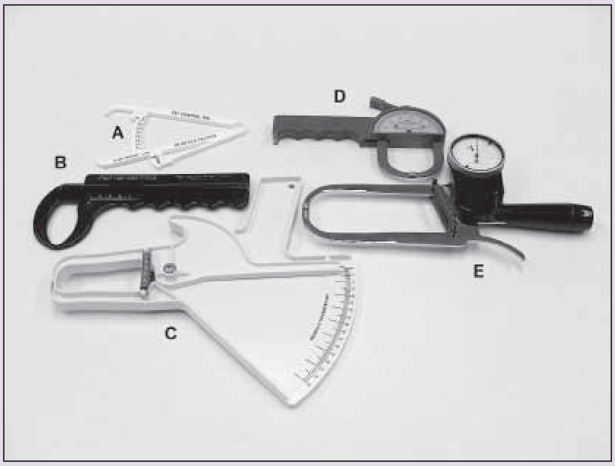

Figure 2. BIA Devices

The Tanita foot-to-foot with desktop display (left), and the Omron hand-to-hand device (lower right).

basic knowledge of these methods may further the physical educator's understanding of body composition research, a discussion of them is beyond the scope of this article. The reader is referred to other sources (Heymsfield, Lohman, Wang, & Going, 2005; Heyward, 2002; Kaminsky & Dwyer, 2006) for further information on these methods.

Measurement of one or more skinfold thicknesses is one of the most popular methods of assessing body composition in physical education. The prediction of %BF using the sum of skinfolds is based on the principle that the thickness of subcutaneous fat is proportional to the total amount of body fat. However, because the proportion and distribution of subcutaneous fat varies with age, gender, ethnicity, and other factors, many equations have been developed using various combinations of skinfold measurement sites to predict %BF. Because there are different anatomical descriptions of skinfold measurement sites and different measurement techniques, physical educators must select the appropriate equation to use and follow the author's description of the skinfold sites and measurement technique. Physical educators should use the same type of caliper (figure 1) used in the original research that derived the prediction equations. A description of skinfold measurement sites and a list of equations can be found elsewhere (Heyward, 2002; Whaley, Brubaker, & Otto, 2006). The sum of two (tricep and calf) skinfold methods and the equations of Slaughter et al. (1988) are commonly used for children and adolescents. Accurate estimates of %BF are possible when the measurements are taken by a trained and experienced physical educator using a quality skinfold caliper. The typical SEE for skinfold predictions of %BF is ±3 to 3.5% body fat.

Bio-electrical impedence measures the body's impedance to a low-level current conducted through the body. The measured impedance is related to the size and shape of the body and the amount of water in the body. Since a large proportion of skeletal muscle is water, the measured impedance can be used to estimate total body water, which in turn can be used to estimate the FFM. Factors affecting the water content of the FFM will affect the accuracy of the predicted %BF. Hydration status can be affected by recent physical activity and exercise, fluid consumption, timing of the last meal, caffeine consumption, and menstruation. New models of BIA devices (figure 2) measure resistance hand-to-hand (Omron Healthcare Inc., Vernon Hills, IL) or foot-to-foot (Tanita Corp., Tokyo, Japan). Both hand-to-hand and foot-to-foot devices can be used individually with minimal instruction and take about one minute. These devices are automated, allowing students to enter their age, gender, height, and weight into the device, which then measures resistance and displays %BF. Not all BIA devices have equations for children and adolescents. The SEE for BIA ranges from ±3.5 to 5.0% body fat.

Body mass index (BMI) has become a popular measurement in children, adolescents, and adults. BMI is not an estimate of body composition, but an indicator of obesity, and it is often used as an outcome measure of many physical activity interventions and physical education programs. Body mass index is calculated as weight (in kilograms) divided by height (in meters squared). Weight in pounds can be converted to kilograms by dividing by 2.2. Height in inches can be converted to meters by multiplying by 0.0254. A student who is 5-foot, 6-inches tall and weighs 140 pounds has a BMI of 22.6 kg/m^2.

Assessing Body Composition in Physical Education

Physical education teachers must be sensitive to each student's need to maintain confidentiality of personal body-composition assessment results. Assessments should be simple to administer and not require students to expose body parts normally covered by their physical education attire. Methods should allow the private and noninvasive assessment of body composition. Equipment that shows results on display screens should be positioned so that the results are not easily seen by other students in the class. It should be clear that the assessments performed in class are for informative and educational purposes and that sharing of personal information is completely voluntary. Students should respect other students' wishes to maintain modesty, privacy, and confidentiality. The physical educator should never encourage or condone the comparing of results.

Assessment of students' body composition in a physical education class should be preceded by a lesson on body composition, its implications for health and physical fitness, how it is measured, and the interpretation of results. To minimize the number of questions that will certainly arise at the time assessments are made, physical educators should describe and demonstrate the assessment process and how the results are interpreted, giving examples of validity and reliability. Lessons provide the forum in which many of the students' questions can be addressed before assessments are made. Students should receive handouts that summarize appropriate interpretation of results, including the likelihood of error and the fact that the assessment is only a prediction of body composition.

Selecting a Method to Use

Accurate assessment of body composition in children is hindered by the fact that children mature and grow at different rates and reach puberty at different times. It cannot be assumed that all boys and girls of the same age are in the same stage of development. Thus, even in a group of boys or girls of the same age, physical educators might find that results of body composition assessments are quite variable. Prediction equations should be based on research in children and adolescents of similar ages as the students in your class.

Selection of a method to use may be based upon a variety of factors, including, but not limited to, cost, size and portability, ease of use, technical complexity, and validity and reliability of measurements in children and adolescents. Measurement of skinfold thickness and electrical impedance are the two methods of assessing body composition in children that are most feasible in physical education settings. Physical educators should select a method most appropriate for use in their educational system.

Skinfolds. Several types of calipers are available (figure 1). Although most calipers are durable, careless handling of Lange and Harpenden calipers may result in the need for manufacturer recalibration. With practice, physical educators can easily learn how to take accurate skinfold-thickness measurements. The Slaughter et al. (1988) equations, used to predict %BF in children and adolescents from the sum of the tricep and calf skinfolds, are widely employed in body composition research. These two sites usually can be measured without exposing body parts normally covered by physical education attire. Although the measurement of skinfold thickness is nonthreatening for most children, some students may perceive the process to be intrusive in that the physical educator must touch their body in a way that will reveal body fatness. Skinfold measurements are easy to conceal and keep confidential. Since children and adolescents typically want immediate feedback from assessments, one disadvantage is that skinfold measurements must be converted to %BF. From the physical educator's perspective, this is an advantage, because it helps maintain confidentiality that might otherwise be violated if results were immediately available. Physical educators can place some of the burden of maintaining confidentiality on the student by teaching students how to use conversion tables provided during the lessons given in earlier class periods. Skinfold measurements are stable over time and are therefore relatively unaffected by physical activity, hydration, menstruation, time since the last meal, and other variables that are difficult to control in a physical education setting. If for some reason the student and/or physical educator has difficulty interpreting the results, actual skinfold measurements (rather than %BF values) can be compared between multiple assessments taken over the course of the semester.

Bio-electrical Impedence. Either hand-to-hand or foot-to-foot electrical impedance machines are available (figure 2). The major benefit of using BIA devices is that students can assess their own %BF in about one minute. Instructions are easy to follow, and there is a minimal learning curve. The fully automated systems measure and record electrical impedance and then quickly calculate and display %BF, providing immediate feedback to the student. Although immediate feedback is important to most students, use of BIA devices that display and/or print results may lead to the violation of confidentiality. This is especially true in physical education classes in which students are curious of how other students perform and are naturally inclined to compare results. The disadvantage of BIA devices is the variability in results due to factors that may affect the hydration status of the student. Large differences between day-to-day assessments can be expected. Manufacturers of BIA devices use equations found in the literature or their own proprietary equations to predict %BF. In addition to the electrical impedance measurement, prediction of %BF is usually based on gender, age, height, and weight. Thus accuracy of the predicted %BF is often related to the accuracy of information that the student inputs. A reasonable SEE is ±3.5 to 5.0% body fat. The device selected should be safely portable and durable enough to withstand the effects of handling by several educators and many students in a variety of settings.

Interpretation of Results

The interpretation of BMI is often misleading, especially in children and adolescents who are still growing. BMI is not a measure of body composition, but an indicator of the degree of obesity in children and adults. In adults 18 years or older, overweight and obesity are defined as a BMI greater than or equal to 25 kg/m^2 and greater than or equal to 30

Table 2. Minimizing Measurement Error of Body Composition Assessments

- Obtain proper and adequate training.
- Practice assessing body composition of colleagues.
- Make sure the equipment used to make the assessment is functioning properly.
- When using skinfold calipers, use the same brand of calipers used in the research that derived the prediction equations.
- Use the same equipment to make multiple assessments of body composition.
- If possible, calibrate the equipment before each use or on a regular basis.
- Keep a log of your own body composition assessments. When results are questionable, assess your own body composition to determine if the equipment is functioning properly.
- Follow manufacturer's instructions for taking measurements.
- Record measurements correctly.
- Double check your calculations.
- Use prediction equations that match the demographics of your students (age, gender, race, etc.).

kg/m^2, respectively. The equivalent categories in children, "at risk of overweight" (rather than "overweight") and "overweight" (rather than "obesity"), are defined as having a BMI that is greater than or equal to the 85th or 95th percentile, respectively, of the value shown on the age-and-gender BMI growth chart (Centers for Disease Control and Prevention, 2000). Even though the correlation between BMI and %BF is modest, and high BMI values are generally associated with a greater %BF, BMI is a poor predictor of %BF. It is very common for children and adolescents who have not yet reached their growth spurt to have high BMI values. As many of these children reach puberty and grow in height and increase muscle mass, BMI values may eventually normalize. Physical educators who work with children and young adolescents should use great caution in interpreting BMI values. There is no single BMI value that represents being overweight for all children and adolescents. Physical educators should describe the BMI to students merely as a ratio of weight to height that is used to describe one's body weight as being underweight, normal, at risk of overweight, or overweight (the terms applied to children).

The first step in assuring that a body composition assessment result is accurate and can be interpreted correctly is to minimize likely sources of error (table 2). When interpreting %BF values, it is important to remember that what is actually being predicted is the %BF value that would be obtained from the criterion method if it were also used. Predicted values are therefore a prediction of a prediction. One concern in interpreting %BF values is the relatively large SEE of the measurement. Recall that 95% of the values of a criterion method will fall within ±2 SEE of the predicted value. If a student's %BF was predicted to be 18% using BIA, whose SEE is ±5% body fat, then it is highly probable that the value obtained from a criterion method could be as little as 8% body fat and as great as 28% body fat. Because of the relatively large SEE, interpretation of %BF estimates must be done with caution. On the average, the %BF calculations for the class as a whole will be accurate, but an assessment for an individual will be more or less accurate than for others. For example, if three boys had predicted %BF values of 18%, one actually might be close to 18% while the other two may be 8% and 28%. The recommendation by a physical educator to these boys would be much different if they were 8% fat versus 28% fat!

Some students may misinterpret or misperceive their body weight, body shape, or body composition as being too high or too large. When helping students interpret results, the physical educator needs to look for possible sources of error (table 2) and consider other factors that may have contributed to a poor assessment (table 3). For those students whose BMI or predicted %BF is correct, yet above the recommended ranges, the physical educator should encourage them to work toward a healthy body weight and composition through both modest increases in physical activity and improvements in diet (reducing consumption of high fat, high calorie, low nutrient foods). Physical educators ought to be promoting lifetime physical activity and a healthy body weight and composition. Emphasis should be placed on the positive aspects of being physically active in and outside of school. The physical educator should also understand that excess weight may physically or emotionally impede participation in physical education. Improvement in body weight and body composition may lead to increased participation in a variety of activities and improved performance in other fitness assessments.

In children and adolescents, the interpretation of %BF values is particularly difficult because (1) there are no universally accepted %BF tables providing normative values by gender and age, (2) the amount of error may vary considerably between children due to individual patterns of growth and maturation, and (3) there is no single, universally accepted, criterion-measurement method. When assessing body composition, physical educators must choose from among the many normative body-composition tables available in textbooks and programs. Two popular tables for adults are those adopted by the American College of Sports Medicine (Whaley et al., 2006) and reported by Lohman, Houtkooper, and Going (1997). Recommended body-composition ranges for children and adolescents have been proposed by Lohman (1987) as well as by the Fitnessgram/Activitygram (Meredith & Welk, 2004) and Fitness for Life (Corbin & Lindsey, 2005) programs. The Fitnessgram/Activitygram battery of fitness assessments proposes a "Healthy Fitness Zone" %BF for boys

(10 to 20% body fat) and girls (15 to 25% body fat) 5 to 17 years of age. A BMI Healthy Fitness Zone is used to help define the appropriateness of weight for height.

The information gained from a single assessment of body composition is limited since no information from previous assessments is available for comparison. The best use of any method of assessing body composition is to perform repeated measurements at each time point and over time. Two similar assessments taken at the same time indicates that the assessment was probably performed correctly and is reliable. Physical educators could perform fitness assessments at the beginning, middle, and end of a semester or year-long instructional period. This would allow any change in height, weight, and %BF to be noted. The same method ought to be used to estimate body composition each time, using the same instrument (e.g., skinfold caliper) by the same teacher.

Conclusion

The physical educator is in a position to educate students about, and provide results from, the assessment of anthropometrics and body composition. Knowledge of the scientific basis and procedures for assessment and interpretation of body composition will help physical educators fulfill their changing role. The information in this article will help physical educators select a method of body composition assessment that is most feasible for their circumstances. Once measurements and assessment are made, the physical educator can help students make appropriate interpretations of BMI and body composition assessments.

Table 3. Interpreting Body Composition Assessments Thought to Be Erroneous

- Does the student's current body weight, BMI, and body shape concur with the predicted %BF? If so, the predicted %BF may be reasonable. If not, consider other sources or error.
- Is the student currently maintaining, losing, or gaining body weight? Body composition assessments are most accurate when the person is weight stable. When children and adolescents are gaining or losing weight, predicted %BF values, especially from BIA, may be inaccurate.
- Is the student currently experiencing a growth spurt? Height, weight, and body composition may change rapidly during adolescent growth spurts. During this time, predicted %BF values may be inaccurate, especially from BIA.
- If a predicted value is questionable, take another measurement using the same method or another method, if available, to see whether the measurements agree. Errors in taking skinfold measurements can easily inflate predictions of %BF. Several variables can influence BIA measurements.
- When all else fails, actual skinfold-thickness measurements (rather than the %BF) can be compared to previous or future measurements.

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