ASSESSMENT OF BODY COMPOSITION TECHNIQUES: A REVIEW OF LABORATORY AND FIELD METHODS

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Abstract
Body composition is the total components of which the body is made up. The body is made up of both fat and fat–free components. While the fat component is simply referred to as fat mass, the fat-free component termed lean body mass, includes bones, organs, tendons, muscle and others. While appropriate concentration of body fat is required for optimum health and maintenance of life, excessive accumulation of fat is associated with poor public health conditions, resulting in chronic, life threatening diseases, such as cardiovascular diseases, diabetes, stroke and cancer of various kinds. Body fat reduces health related physical fitness and lowers the ability to perform activities requiring sustained effort. In order to maintain appropriate concentration of body fat, periodic assessment of body composition is inevitable. Therefore, this paper discusses the commonly used laboratory and field based techniques of body composition assessments, including hydrodensitometry, bioelectrical impedance analysis, dual energy x-ray absorptiometry, body mass index, skinfolds and body circumference measurements. Although, laboratory methods are more reliable, accurate and in some cases easier to carry out than field based tests, however, laboratory equipment are expensive and unavailable to most researchers. Also discussed in this paper are merits and demerits, benefits and procedural precautions of major body composition assessment techniques.

Keywords: Body composition, hydrodensitometry, body density, bod pod, skinfold caliper

Introduction

Body composition, an important health and performance variable is seen as the total components of which the body is made up. William, (2006) defined body composition as the total mass of the body which includes fat and non-fat components. Baumgartner, Jackson, Mahar and Rowe (2007) defined it as the classification of the body into fat weight and fat free weight. The total body weight that is made up of fat component is termed body fat mass, while the weight of the body composed of fat-free components such as muscles, tendons, bones, system organs and connective tissues is referred to as lean body weight (Iro, 2008). Studies have revealed that excess body fat is associated with poor public health conditions, resulting in various medical problems including hypertension, diabetes and heart diseases (Baumgartner, et.al, 2007). The

consequence of which is increased morbidity and reduced longevity. Excess body fat reduces health related fitness and lowers the ability to perform many activities that require sustained effort, work inclusive (Alker, Wang, Pbert, Thorsen &Lemon, (2015). However, acute absence of body fat is not desirable either. Therefore, appropriate body composition is essential for good health and maintenance of life.

There are two classes of fats found in the body, namely: essential fat and storage fat. As the name implies, essential fat is needed for life and a healthy body. Ogunleye and Vipene (2013) described essential fat as that required for normal physiological functioning of the body and without it poor health is inevitable. Essential fat could be found within and around tissues such as muscles, nerve cells, bone marrow, intestines, heart, liver and lungs is important for general health, physical appearance and for maximizing athletic performance (Baumgartner et.al, 2007). Excess stored fats especially around visceral muscles (fat stored in the abdomen and around vital organs, such as the heart, the intestine, the liver and others) pose a lot of health risks. These constitute unnecessary weight burden and increase the risk of developing degenerative diseases such as heart diseases, coronary artery disease, hypertension, type 2 diabetes, obesity, stroke, kidney disease, liver disease and certain cancers (Nikolaidis, 2013). Based on the above stated reasons, accurate measurements of percent body fat are needed to assess the individual's fat status in order to develop quality preventive measures to stem down the tide. Assessment of the body fat makes it easier to prevent and manage obesity which is a major risk factor for most chronic diseases.

Assessment of body fatness is one of the major achievements of sports scientists (Baumgartner, et.al. 2007). Various methods of assessment have been discovered and used over the years. In this paper, the author provides the most common methods for assessing body composition, some of which are laboratory based, while others can be used in the field. Laboratory methods of measuring body composition include Dual Energy Xray Absoptiometry (DEXA), Bio-Electrical Impedance Analysis (BIA), Hydrodensitometry (underwater weighing) and Air Displacement Plethysmosgraphy. While Body Mass Index (BMI) assessment, skinfolds and Body circumference measurement are common field based techniques often used in the assessment of body composition. A brief discussion of some of these methods is inevitable for proper understanding and education purposes. Moreover, understanding the methods for evaluating body composition

discussed in this paper can be useful to identify people, children and youths at the risk of becoming obese adults.

Hydrodensitometry

Hydrodensitometry, also known as hydrostatic weighing or underwater weighing is the most commonly used laboratory method of evaluating body composition (Baumgartner et.al, 2007). The objective of underwater weighing is to measure the volume of the body, which is used alongside body mass to calculate the subject's body density. Body density is a value required for calculating percent body fat. It is a bit tasking to determine the volume of an irregularly shaped object or body, and more tasking when it comes to human bodies. Hydrostatic weighing involves placing the participant in a specially designed underwater chair that is attached to a scale, which is submerged completely in water to measure body weight under water (Nieman, 2011). However, prior to entering the tank the participant weight must be taken and lungs exhaled completely in order to keep the standard error of estimate as low as possible. Hydrostatic method of assessing body composition is based on the assertion that fat tissue is less dense compared to lean tissue. A body consisting more of fat tissues floats while the ones with more fat-free tissues sink in water (William, 2006).

When overweight/obese subjects are hydrostatically weighed, scuba weight belt may be placed on the subject's laps, however, the weight of the chair and the scuba weight belt must be subtracted in order to obtain a truly underwater weight (Baumgartner, 2007). Having obtained the weight of the subject underwater and on land, the tester can now calculate the subject's body volume by subtracting his weight underwater from his weight on land and dividing the score by the value of the water density.

Finally, the tester subtracts the value of the participants' body air components from the score to determine the subject's body volume. According to Baumgartner, et.al (2007), Siri Formula (% body fat=(495/BD)-450,) or Brozek Formula (% body fat=(457/BD)-414, may be used to calculate percent body fat from body density. Underwater weighing is often referred to as the gold standard for body composition analysis due to its' very low standard error of estimate, high accuracy and reliability (Igbanugo, 2006). Unfortunately, water tank, underwater chair and other equipment are expensive and unavailable to researchers (William, 2006). Furthermore, participants who are scared of water may find it uncomfortable to be submerged and or hold their breath underwater. Moreover, underwater weighing is time consuming, therefore it's

not a suitable method in any study involving large sample size (Duren, Sherwood, Czerwinski, Lee, Choh, Siervogel,& Chumlea, 2008).

BOD POD/Air Displacement Plethysmography

Another body density method of estimating body composition is the use of Bod Pod or Air-Displacement Plethysmography to determine the body volume, which in turn is used to calculate body density. According to Bumgartner, et.al, (2007) this method is based on Boyle's law, which states that the pressure of a gas varies inversely with its volume. The only equipment required for this method is a machine known as Bod Pod or body box. Bod Pod measures the amount of displaced air when the participant sits in it (William, 2006). First, the tester takes the air pressure of the empty box and next, the pressure of the filled box. Then the assessor compares the air pressure of the empty box with the air pressure of the filled box to determine how much air is displaced by the participant. By measuring how much air is displaced by the participant, the tester can determine body volume and thereafter, density. Like underwater weighing, the participant body density is then used to analyse his body composition. The major advantage of body box over underwater weighing is that, it is easy to use and many participants can be tested within a short period of time (Baumgartner, 2007). It is actually a method of choice in studies involving large populations; it is fast, comfortable and reliable. However, body box is expensive; therefore, it is not easily accessible to researchers (William, 2006).

Dual-Energy X-Ray Absorptiometry (DEXA)

Dual energy X-ray Absorptiometry is a direct method of estimating body composition, popularly used by medical practitioners where the body is exposed to a high and a low energy x-ray beam. Using DEXA the subject is made to assume a prone position on a table, where a complete total body scan is done by the machine. Dual-Energy X-Ray Absoptiometry helps to divide the body into three major components of total body bone mineral, fat-free soft tissue and fat mass components. Generally, percent body fat is computed as a ratio of total body fat mass and body weight. Dual-Energy X-Ray Absoptiometry, in addition to being a fast method of estimating body composition is user-friendly for the tester and the participant. It takes not more than 20 minutes to carry out a whole body scan. The major advantage DEXA has over hydrostatic weighing is that it can be used for participants who are scared of water, children, older people and those who are ill

(Baumgartner, et.al, 2007). Due to ease of use, scientific validity, time efficiency DEXA can be described as the best laboratory measure of body composition. Conversely, studies revealed that DEXA estimates of body composition are usually affected by the equipment models and software employed, methodological problems, large body size and intra- and inter-machine differences (Duren, Sherwood, Czerwinski, Lee, Choh, Siervogel & Chumlea, 2008).

Bioelectrical Impedance Analysis

The use of bioelectrical impedance analysis involves the measurement of resistance to the flow of electrical current through the body between selected points. Bioelectrical impedance analysis of body composition is used to estimate total body water (TBW), fat-free mass (FFM), and fat mass by measuring the resistance of the body as a conductor to a very small alternating electrical current (Chumlea &Guo, 1994). This method is based on the principle that electricity will choose to flow through the tissue that offer the minimum resistance. Scientific evidences show that fat is a poor conductor of electric current when compared with fat free tissue (Edward & Dixie, 2017). Therefore, the higher the amount of body fat the greater the resistance of the body to the passage of electric current (William, 2006). Thus, the bioelectrical impedance analysis estimates percent body fat by measuring bioelectrical resistance of the body. As fast, simple and comfortable bioelectrical impedance analysis is, it has some powerful shortcomings that threaten its validity and reliability. One is the problem of hydration. If the body is dehydrated, it tends to overestimate percentage of body fat compared to what is obtainable at normal hydration. Secondly, the large predictive errors inherent in BIA make it insensitive to small improvements in response to treatment (Chumlea, 2006).

Skinfold Thickness Measurement

One popular and very efficient field method of assessing body composition is skinfold thickness measurements. Studies revealed that about 50 percent of total body fat is contained in the subcutaneous fat layers and can be used to predict the total body fat (Baumgartner, et.al. 2007). Skinfold thickness is measured with the aid of caliper. Skinfold caliper is a specially designed instrument for measuring a double thickness of subcutaneous fat at certain body locations. Measurements obtained from this instrument are used to determine percent body fat of an individual using standardized equations provided by professionals. There are several types of skinfold calipers in the markets, however, testers are mandated to use the ones

approved by the National Research Council of the United States (Baumgartner et.al, 2007). Calipers should be accurately calibrated and have a constant pressure of 10 grams per square millimeter (g/mm) throughout the full measurement range (Nikolaidis, 2013). When used correctly, data obtained through skin fold calipers can provide an estimate of percent body fat that has a high correlation (*r* .80) with underwater weighing, DEXA, and other body composition testing standards. When taking skinfold measurement, the first thing to do is to identify the skinfold sites. In most studies, sum of three skinfolds is used in determining percent body fat in both men and women (Ogunleye & Vipene, 2013). However, one can also use sum of two or seven skinfolds (Baungartner, et.al, 2007).

Using sum of three skinfolds, men's skinfolds measurements are taken from the chest, abdomen and thigh while triceps, suprailium and abdomen are recommended skinfold sites for women. The tester will need to mark the skinfold sites with marker for easy identification. The tester then pinches and pulls the skin with his left hand while holding the caliper in his right hand, thus, the left handgrasps the skinfold firmly with the thumb and index finger, while the caliper is kept perpendicular to the skinfold. The caliper grip is then released to exert full tension on the skinfold, after which the tester reads the dial to the nearest 0.5mm. Minimum of two measurements will be taken on each site and if measurements vary by more than 1mm the third one will be taken to clear all doubts. The average of the two measurements that seem to be the best is used as a measure of the skinfold fat site. The scores obtained from the three sites are then added together and used in estimating the participant's percent body fat using the equation given by the experts. The major threats to the validity and reliability of skinfold measurement include not using a suitable caliper, lack of trained technician and not measuring at the right site. Harpenden, Skyndex-1 and Slim guide calipers are often recommended for use among others due to their high accuracy and reliability (Nieman, 2011).

Body Mass Index

Generally, people with higher body weights will have higher body fat; therefore, body weight is the most frequently used measure of overweight and obesity. While overweight is having more weight than required for ones height and age, obesity is a condition which predisposes an individual to health and social problems due to excess fat. Body Mass Index is a more reliable tool that uses height and weight to categorize people into different classes. Body Mass Index is simply the ratio of body weight in kilogram to the height per square meter; it is a fast

and easy method of determining whether or not the weight of a person is appropriate for his height (Social Policy Evaluation and Research Unit, 2015). The outcome of this calculation is then compared to already prepared BMI reference table in order to determine the subject's weight status Thus, people can be classified as underweight (BMI≤18.5kg/m^2), normal weight (18.5-24.9 kg/$m^{2\leq}$), overweight (25-29.5 kg/m^2) or obese (≥30 kg/m^2). Although BMI is a descriptive index of body physique, it offers a lot of advantages, including availability of national reference data, ease of use and application to large populations (Edward & Dixie, 2017). However, the major problem with body mass index is its inability to differentiate between fat weight and fat free weight. Therefore, athletes who are highly muscular, with large bones may exceed the World Health Organization standards for over-weight or obesity with regards to their BMI.

Body Circumferences

Measuring body circumferences is another field based indirect technique of estimating body composition. It is very easy, quick and accurate. Here, body density is calculated from combinations of body circumferences, including those of the waist (abdomen), hip (buttocks) neck, arm and leg (Duren, et.al. 2008). However, while there are few reference data available on arm and leg circumferences which is the major factor limiting their usage, the abdominal and hip circumferences are popular among the researchers because of their high correlational values and availability of reference data.

Studies have shown that human body stores fat in abundance around the waist and hip and that higher abdominal and hip circumferences indicates the presence of obesity (Baumgartner, et.al 2007). Large amount of visceral adipose tissue in the waist or abdomen is an indicator of centralized obesity, also known as android obesity (William, 2006). People with central, visceral obesity are particularly at the risk of cardiovascular diseases, hypertension, type 2 diabetes, liver disease and cancer (Britton, Massaro, & Murabito, 2013; Doyle, Donohoe & Lysaght, 2012). Therefore, as values of waist-hip-ratio increase, the risk of degenerative diseases, particularly, heart attack increases. According to a study carried out by Yusuf, (2005), as quoted by Baumgartner, et.al. (2007), participants of all ages and ethnic groups had a significantly increased risk of heart attack when waist-hip-ratio was 0.90 or greater in men and 0.83 or greater in women. Generally, waist-to-hip ratios greater than 0.85 represent a centralized

distribution of fat; most men with a ratio greater than 1.0 and women with a ratio greater than 0.85 are at increased risk for cardiovascular disease, diabetes, and cancers (Duren, et.al. 2008). Waist and hip circumferences are usually measured manually using flexible non-stretchable tapes and in accordance to the World Health Organization (WHO) guidelines (Jaeschke, Steinbrecher & Pischon, 2015). According to these guidelines, waist circumference is assessed at the midpoint between the last rib and the iliac crest, sometimes on the navel, while the hip circumference is measured at the level of the largest lateral extension of the hips (Lennie, Amofa-Diatu, Nevill & Stewart, 2013). Both measurements must be taken horizontally and without mounting pressure on the body (Sebo, Beer-Borst, Haller & Bovier, 2008). However, accurate measurement of waist and hip circumferences is often faced with certain difficulties. It is time consuming and may require assistance, especially in obese participants (Verweij, Terwee, Proper, Hulshof, & Van-Mechelen, 2013)

Other techniques that can also be used in body composition analysis include**,** magnetic resonance imaging, total body counting, near infrared light interactance, computed tomography and many more others. Interested scholars are advised to consults good texts authored by professionals to study then.

Conclusion and Recommendation

The accurate determination of body composition, especially total body fat (internal and subcutaneous) is an important health issue. Internal fat, in particular, visceral fat, is a critical factor in the development of chronic diseases such as hypertension, type 2 diabetes, stroke, liver diseases and cancer, which are consequences of obesity. Accurate and early determination of body fat level through the various techniques discussed in this paper will certainly help to nip in the bud these health issues. Techniques discussed in this paper include hydrodensitometry, air displacement plethysmography, bioelectrical impedance analysis, dual energy x-ray absorptiometry, skinfolds thickness measurement, body mass index and measurement of body circumferences. Although, laboratory methods are more accurate and easy, they can be expensive and sometimes unavailable to researchers. Generally, skinfold thickness measurements and body circumferences are favoured by researchers, largely because they are moderately accurate, easy to use, less expensive and suitable for large population studies.

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