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Physical Activity and Body Composition

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Public health guidelines focus primarily on the promotion of physical activity and steady state aerobic exercise, which enhances cardiorespiratory fitness and has some impact on body composition (BC). BC is an essential measure of health and fitness for both athletes and the general population.

Research demonstrates that resistance exercise training has profound effects on the musculoskeletal system, contributes to the maintenance of functional abilities, and prevents osteoporosis, sarcopenia, lower back pain, and other disabilities. Recent research demonstrates that resistance training may positively affect risk factors such as insulin resistance, resting metabolic rate, glucose metabolism, blood pressure, body fat, and gastrointestinal transit time, which are associated with diabetes, heart disease, and cancer [1].

Physical activity has an effect on BC, especially on skeletal muscle. Skeletal muscle is the largest nonadipose tissue component at the tissue-system level of body composition in humans and it plays an important role in physical activity and many biochemical processes [2]. Fat-free mass (FFM) has commonly been used as a surrogate measure of skeletal muscle mass but does not always accurately reflect specific changes in muscle mass or differences in muscle mass among individuals. A fairly new approach to assess BC is to measure body cell mass (BCM). BCM is defined as the total mass of 'oxygen-exchanging, potassium-rich, glucose-oxidizing, work-performing' cells of the body [3]. A total body potassium (TBK)-independent BCM prediction model on the basis of an earlier model has been developed by Wang et al. [4]. They have provided a physiologically based, improved, and validated TBK-BCM prediction formula that should prove useful in BC and metabolism research.

Physical activity appears to have a beneficial effect on bone mass. Furthermore, physical activity with greater mechanical loading appears to result in a greater bone mass than non-weight-bearing activities, and there appears to be a site-specific skeletal response to the type of loading at each bone mineral density site [5]. This has also been demonstrated in a study of girls affected by eating disorders and in athletes of the same age [6].

An assessment of fat-free mass (FFM) and fat mass (FM) provides valuable information about changes in BC with weight gain or loss and physical activity, and during aging. Noninvasive bedside techniques can now be used to evaluate the nutritional status of healthy and ill individuals [7].

Since body mass index has been shown to be an imprecise measurement of fat-free and FM, and provides no information if weight changes occur as a result of a decrease in FFM or an increase in FM. Non-invasive BC methods (i.e. bioelectrical impedance analysis (BIA), air displacement plethysmography) can now be used to monitor FFM and FM with weight gain and loss, and during aging.

Methods to Assess Body Composition

Depending on what information is needed, several methods are available, each with some advantages and limitations [8, 9] to measure BC. Cost of the method (both the instrument itself and the requisite personnel), the eventual stress and danger for radiation exposure for the subject, and the time necessary to obtain the information, as well as the accuracy needed are factors to be considered in the choice of the method.

The measurement of BC is of interest to medical personnel, nutritionists, and sports scientists. The most common and frequently used methods are based on a two-component model comprising FM and FFM because the amount of fat in the body is of special nutritional interest. The three most common methods used to calculate BC based on the two-component model are underwater weighing (UWW), BIA and skinfold thickness measurements.

UWW has been used as the reference method since the beginning of the1950s and is based on the assumption that fat has a density of 0.9 g/cm^3 and the FFM has a constant density of 1.1 g/cm^3 [10].

Skinfold thickness measurement has been used as a simple and inexpensive method to estimate the percentage fat since Durnin and Womersley [11] found a relation between the skinfold thickness measured with caliper and body density measured by UWW. To calculate body fat percentage Siri's 2-components equation was used based on the aforementioned assumed fixed densities for FM and FFM.

BIA is an indirect way to measure total body water (TBW) from total body resistance [12]. BIA is also a relatively simple method and is suitable in field studies [13, 14]. From the estimation of body water, body fat content has been calculated on the assumption that FFM contains 73.2% water.

The two-component model assumes that there is a fixed proportion of water, protein and mineral in FFM. However, bone mineral mass, water and protein vary among individuals and are influenced by age, sex ethnic and genetic factors, as well as diet and exercise.

A more valid and precise method for measuring BC is dual-energy X-ray absorptiometry (DXA). DXA divides the body into three components: bone, fat-free and bone-free tissue, and fat [15].

A recent method to measure body fat is air-displacement plethysmography. The use of air-displacement plethysmography (BodPod) correlates with the concept of hydrostatic weighing (underwater weighing). Instead of using water to measure body volume, the BodPod uses air displacement to measure body volume [16].

Whole-body counting of ^{40}K enables, using a noninvasive nuclear technique, the in vivo determination of the naturally occurring radioactive isotope of ^{40}K in the human body. Because ^{40}K is 0.012% of natural potassium, it provides an accurate assessment of TBK. Potassium is almost exclusively an intracellular cation (95%) that Moore et al. [3] found chiefly in muscle and viscera (hence, essentially not found in fat, bone, or extracellular water). These authors considered TBK concentrations to be linearly correlated with the size of the BCM. An accurate measure of BCM would prove extremely useful to establish an individual's nutritional state or degree of malnutrition [17].

Factors such as age, gender, level of adiposity, physical activity and ethnicity influence the choice of method and equation. It is also important to evaluate the relative worth of prediction equations in terms of the criterion method used to derive reference measures of BC for equation development [18]. Given that hydrodensitometry, hydrometry and DXA are subject to measurement error and violation of basic assumptions underlying their use, none of these should be considered as a 'gold standard' method for in vivo BC assessment. Reference methods, based on whole-body, two-component BC models, are limited particularly for individuals whose FFM density and hydration differ from values assumed for two-component models. One multi-component model approach adjusts body density (measured via hydrodensitometry) for TBW (measured by hydrometry) and/or total body mineral estimated from bone mineral (measured via DXA). Skinfold (SKF) and BIA are two BC methods used in clinical settings. Unfortunately, the overwhelming majority of field method prediction equations have been developed for specific populations and are based on two-component model reference measures [19]. However, when assumptions generally accepted for the healthy population may not be valid for particular groups of individuals such as the elderly and athletes the multicomponent models of BC need to be considered. Multicomponent models have been developed in recent years in order to provide estimates of the various components of the FFM, as well as the distribution of the adipose mass. They can be useful in situations where it is likely that the composition of the FFM is altered, when the simple two-component model cannot be applied [20].

Body Composition and Physical Activity

There is considerable interest in the evaluation of BC with regard to exercise and sport, because it is known that BC has a significant effect on athletic performance and that exercise has the potential to alter BC. Nonetheless, fluctuations in body weight alone cannot be adequately interpreted unless the quantitative variations of the components (FFM, FM, and TBW) are taken into account, because each component varies independently.

Information on BC of groups of athletes can be important since BC is an indicator of nutritional status and provides information on acute water homeostasis. Furthermore, BC provides information on specific adaptations to different physical training regimens.

Football (soccer), judo and water polo represent three uniform sports. However, all three are similar in that they are comprised of aerobic and anaerobic components. Thus, assessing and comparing the BC of these similar, yet different, sports would provide new insight into the field of BC.

Presently, the ‘gold standard’ for quantifying BCM is via measurement of the naturally occurring isotope ^{40}K. Nonetheless, these methods are expensive, time-consuming, and not practical for use in the field.

Bioelectric impedance (BIA) is a method for estimating BC and is one of the most widely used techniques in the study of BC. BCM can be measured by BIA and bioimpedance spectroscopy (BIS) [21, 22], which would allow for increased assessment of BCM because of the ease and inexpensiveness of both BIA and BIS. Furthermore, because BCM represents the functional parameters for metabolism and strength, evaluating BCM in athletes could be a better predictor of athletic performance and health, compared to simply assessing FFM and FM.

Andreoli et al. [23] assessed the impact of different sports on BCM in professional athletes using BIS. Although there were no significant differences in body weight and FFM among the groups, FM, %BF, and BCM varied considerably. They found that BCM was significantly different between the football divisions according to their performance, as well as between control group and all other teams. The BCM of these non-athletes was lower than the BCM of athletes, confirming the high level of fitness of the professional athletes.

Measurement of BCM is the best predictor of muscular efficiency, which could predict athletic performance. Therefore, increases in FFM and BCM are related to increase in muscular efficiency, and the lower BCM reported in non-athletes signifies decreases in muscular efficiency. Thus, the assessment of BCM by BIS could be a practical, as well as extremely useful tool, in evaluating BC and metabolism in athletes. BCM measured by BIS can assist researchers and coaches in more accurately assessing BC in athletes, without considerable time and expense.

Body Composition and Aging

Aging is associated with changes in BC, including an increase and redistribution of adipose tissue and a decrease in skeletal muscle and bone mass, beginning as early as the fourth decade of life. Aging is associated with a decline in bone mass, skeletal muscle mass, strength, and physical work capacity. Women are more likely to suffer from these physical changes than men. These changes have significant implications for the health and functioning of the individual because of their associations with chronic disease expression and severity, as well as geriatric syndromes such as mobility impairment, falls, frailty and functional decline. Therefore, understanding the preventive and therapeutic options for optimizing BC in old age is central to the care of patients in mid-life and beyond. Pharmacological interventions are currently available for maintaining or improving bone mass, and much current interest is focused on anabolic agents that will preserve or restore muscle mass, as well as those that can potentially limit adipose tissue deposition. There is currently sufficient evidence to suggest that a substantial portion of what have been considered 'age-related' changes in skeletal muscle, fat and bone are in fact related either to excess energy consumption, decreased energy expenditure in physical activity, or both factors in combination. In addition, selective underconsumption of certain macro- or micronutrients contributes to the loss of skeletal muscle and bone mass [24].

Aging is associated with a decline in FFM. Sarcopenia is the loss of skeletal muscle mass that occurs to ageing. However, the rate of sarcopenia and the severity of its sequelae vary greatly according to health status, physical activity, and possibly diet [25].

The question is whether age-related changes in BC can be delayed by an active life style. Although no effect of habitual activity level on changes in BC has been observed, training has a positive effect on skeletal muscle function [26].

Sedentary persons who improve their physical fitness are less likely to have an increased risk of cardiovascular disease than are those who remain sedentary.

There now exists a wealth of data demonstrating that physical activity and exercise may impruve disease and delay decline in function in the geriatric population. However, many healthcare professionals do not feel adequately prepared to design and prescribe exercise programs for their patients. Healthcare providers are strongly encouraged to promote a less sedentary life style for their older patients, which may improve the quality of life in these older individuals [27].

An accurate measure of BCM would prove extremely useful to establish an individual's state of health or disease over time, possibly assisting with the prevention of sarcopenia. De Lorenzo et al. [28] evaluated BCM in a cohort of Italian men in order to assess differences in BC with age. They did not find differences in body weight among decades; however, TBK, TBK/height, TBK/body weight, and BCM was found significantly lower in the oldest subjects compared to the other groups. Results confirm that there is a major decrease in BCM with age, and in a weight stable subject, BCM may be decreased, which may lead to reduced functional capacity [28].

It is to be noted that since body mass index (BMI) is largely used in sport medicine, an observation should be pointed out here, BMI does not discriminate body fat from FFM nor does it detect changes in these parameters with physical activity and aging. Body FM index (BFMI) and FFM index (FFMI) allow comparisons of subjects with different heights. Kyle et al. [29] evaluated differences in body mass index, BFMI, and FFMI in physically active and sedentary subjects under and over 60 years and determined an association between physical activity, age and BC parameters in a healthy white population between the ages of 18 and 98 years. The results show that the physically active as opposed to sedentary subjects were more likely to have a low BFMI and less likely to have a very high BFMI.

Conclusions

The earlier in life an individual becomes physically active the greater the increase in health benefits; however, becoming physically active at any age will benefit overall health. Improvement in musculoskeletal fitness (for example, through resistance training combined with stretching) is related to an enhanced health status. Thus, maintaining musculoskeletal fitness can increase overall quality of life.

A good approach for many individuals to obtain the recommended level of physical activity is to reduce sedentary behavior by incorporating more incidental and leisure-time activity into the daily routine. Political action is imperative to effect physical and social environmental changes to enable and encourage physical activity.

The current physical activity guideline for adults of 30 min of moderately intense daily activity, preferably every day of the week, is of importance in limiting health risks for a number of chronic diseases including coronary heart disease and diabetes. However, to prevent weight gain or weight regain this guideline is likely to be insufficient for many individuals in the current environment.

Athletic staff should be knowledgeable about the latest guidelines related to weight and appropriate weight control methods so they may guide their athletes using modest, safe approaches that will not negatively affect health or performance.

Regular physical activity has profound effects on BC and helps to maintain and increase skeletal muscle mass, with increased resting metabolic rate and enhanced capacity for lipid oxidation during rest and exercise.

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