Experimental Gerontology 48 (2013) 1479–1488

Contents lists available at ScienceDirect

Experimental Gerontology

journal homepage: www.elsevier.com/locate/expgero

Simplified method of clinical phenotyping for older men and women using established field-based measures

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ARTICLE INFO

Article history:
Received 21 August 2013
Received in revised form 2 October 2013
Accepted 8 October 2013
Available online 16 October 2013

Section Editor: Christiaan Leeuwenburgh

Keywords:
Body composition
Sarcopenia
Obesity
Sarcopenic-obesity
Phenotype
Isoperformance

ABSTRACT

The purpose of this investigation was to determine body composition classification using field-based testing measurements in healthy elderly men and women. The use of isoperformance curves is presented as a method for this determination. Baseline values from 107 healthy Caucasian men and women, over the age of 65 years old, who participated in a separate longitudinal study, were used for this investigation. Field-based measurements of age, height, weight, body mass index (BMI), and handgrip strength were recorded on an individual basis. Relative skeletal muscle index (RSMI) and body fat percentage (FAT%) were determined by dual-energy X-ray absorptiometry (DXA) for each participant. Sarcopenia cut-off values for RSMI of 7.26 $kg \cdot m^{-2}$ for men and 5.45 $kg \cdot m^{-2}$ for women and elderly obesity cut-off values for FAT% of 27% for men and 38% for women were used. Individuals above the RSMI cut-off and below the FAT% cut-off were classified in the normal phenotype category, while individuals below the RSMI cut-off and above the FAT% cut-off were classified in the sarcopenic-obese phenotype category. Prediction equations for RSMI and FAT% from sex, BMI, and handgrip strength values were developed using multiple regression analysis. The prediction equations were validated using double cross-validation. The final regression equation developed to predict FAT% from sex, BMI, and handgrip strength resulted in a strong relationship (adjusted $R^2 = 0.741$) to DXA values with a low standard error of the estimate (SEE = 3.994%). The final regression equation developed to predict RSMI from the field-based testing measures also resulted in a strong relationship (adjusted $R^2 = 0.841$) to DXA values with a low standard error of the estimate (SEE = 0.544 $kg \cdot m^{-2}$). Isoperformance curves were developed from the relationship between BMI and handgrip strength for men and women with the aforementioned clinical phenotype classification criteria. These visual representations were used to aid in the classification and evaluation of sarcopenia, obesity, and sarcopenic-obesity in elderly individuals. Future research should replicate the current findings with an increased sample size and the development of tailored interventions for each body composition category.

1. Introduction

After progressively increasing throughout the first four decades of life, skeletal muscle mass begins to slowly decrease, termed sarcopenia, and is linked with a concomitant increase in body fat percentage (FAT%)(Stenholm et al., 2008). Baumgartner termed these changes "syndromes of disordered body composition," or body composition phenotypes, and noted that the association between skeletal muscle mass and FAT% varied with age (Baumgartner, 2000). Despite lacking a consistent definition and etiology for the age-related variations in body composition, it is estimated that the loss of muscle mass in the elderly resulted in health care costs of over $18.4 billion in the United States (Janssen et al., 2004b), and that the number of people over the age of 60 years old affected worldwide could increase to 1.2 billion in the next two decades (Cruz-Jentoft et al., 2010). In response to the ongoing research and potential economic impact involving these multifactorial syndromes, a number of international working groups have been formed to critically define the disorders and to develop diagnostic criteria for clinical use (Cruz-Jentoft et al., 2010; Fielding et al., 2011). While these working groups are serving the clinical and

Abbreviations: BMI, body mass index; RSMI, relative skeletal muscle index; FAT%, body fat percentage; DXA, dual-energy X-ray absorptiometry; SD, standard deviation; SEE, standard error of estimate; TE, total error; CE, constant error.

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http://dx.doi.org/10.1016/j.exger.2013.10.005

research organizations, a systematic approach to the classification of disordered body composition and subsequent selection of appropriate interventions is needed for community-based health care and fitness specialists who may not have access to expensive diagnostic equipment.

Dual-energy X-ray absorptiometry (DXA) is a technique that is commonly utilized to determine lean mass and FAT% in the elderly (Zamboni et al., 2008). Two specific variables from DXA are of interest when examining the phenotypes of body composition in the elderly. These variables are FAT% and relative skeletal muscle index (RSMI), and each examines a specific component of body composition that affects quality of life during aging (Delmonico et al., 2007; Zoico et al., 2004). The determination of RSMI and FAT% from DXA in the elderly provides for the organization of individuals into classifications of normal body composition, sarcopenia, obesity, and sarcopenic obesity. One of the most commonly utilized standards, developed by Baumgartner and colleagues from DXA (Baumgartner et al., 1998), describes sarcopenia as two standard deviations below the mean RSMI of a sample of young adults, which corresponds to 7.26 $kg \cdot m^{-2}$ in men and 5.45 $kg \cdot m^{-2}$ in women. Classification of sarcopenia in the elderly has been related to physical disability, functional impairment, muscle strength, lower extremity function, and mortality (Baumgartner et al., 1998; Delmonico et al., 2007; Newman et al., 2006; Zoico et al., 2004).

Additionally, Baumgartner et al. (1998) defined elderly obesity as FAT% greater than the sex-specific median values for a large cohort of men and women over the age of 60 years old, which corresponded to 27% in men and 38% in women. Classification of obesity in the elderly has been related to functional limitations, lifestyle factors, and insulin resistance, as well as muscle quality (Davison et al., 2002; Gomez-Cabello et al., 2011; Jankowski et al., 2008; Koster et al., 2011). Furthermore, obesity has shown to be a better predictor of physical performance than muscle mass in this population (Jankowski et al., 2008); and Bouchard et al. (2009) reported that obesity might be more closely associated with physical capacity than sarcopenia.

The combination of sarcopenic and obese phenotypes in the elderly has been termed sarcopenic-obesity (Baumgartner, 2000). Increasing prevalence of sarcopenic-obesity has been documented with ~9–12% of elderly men and women over the age of 65 characterized with muscle loss and augmented FAT% (Stenholm et al., 2008). This evaluation may be underestimated due to the possibility of DXA misinterpreting intramuscular fat mass as lean mass in obese individuals (Newman et al., 2003; Zamboni et al., 2008). The combination of low muscle mass and intramuscular fat infiltration has shown to be positively associated with lower extremity function (Visser et al., 2002). Sarcopenic-obesity has been related to decreased mobility and increased disability with regard to activities of daily living (Baumgartner et al., 2004; Stenholm et al., 2008). Baumgartner (2000) showed that sarcopenic-obesity, more than sarcopenia or obesity alone, was associated with physical disability, balance abnormalities, gait abnormalities, and falls in a group of elderly men and women.

Isoperformance curves are lines determined by two or more variables that can be used to demarcate between varying levels of performance (Jones, 2000; Morton, 2009). The use of isoperformance curves has been previously explored in applied psychology and human factors engineering to aid in the process of balancing variables in order to achieve a minimum desirable level of performance as opposed to performance maximization (de Weck and Jones, 2006; Kennedy, 1988; Kennedy, 1992). The classification of body composition phenotypes in the elderly provides a unique opportunity to apply the isoperformance methodology. Prediction equations for RSMI and FAT% from field-based testing measurements, such as body mass index (BMI) and handgrip strength, along with pre-defined cutoff values may be used to differentiate individuals into classifications of normal body composition, sarcopenic, obese, and sarcopenic-obese. BMI, as an indicator of adiposity (Flegal et al., 2009; Heymsfield et al., 2011), may be viewed as a general marker of body weight and shape, while handgrip strength, as an indicator of lean mass (Baumgartner et al., 1998; Baumgartner et al., 1999), may be viewed as a general marker of muscle function and overall physical ability.

The relationship between handgrip strength, BMI, and both lean and fat mass may be employed in an effort to examine body composition phenotypes in the elderly (Arngrimsson et al., 2009; Baumgartner, 2000). The prevalence of sarcopenic-obesity, using handgrip and BMI as indicators, falls between 4 and 9% in individuals over the age 65 years old (Stenholm et al., 2008). Grip strength is higher in elderly men than elderly women, but has only shown to be a significant predictor of appendicular lean mass in men, while BMI was found to be a significant predictor for both men and women (Cawthon et al., 2011; Iannuzzi-Sucich et al., 2002). Therefore, sex may also be related to phenotypes of body composition in the elderly. The evaluation of these field-based testing measurements on an individual basis through the use of isoperformance curves may allow for the determination of appropriate interventions for elderly men and women in each of these body composition phenotype classifications.

The primary purpose of this investigation was to propose a systematic approach to body composition classification using field-based testing measurements in healthy elderly men and women. An additional aim was to devise prediction equations for RSMI and FAT% from BMI and handgrip strength values, and develop isoperformance curves to aid in the classification and evaluation of sarcopenia, obesity, and sarcopenic-obesity in elderly individuals.

2. Methods

2.1. Participants

Baseline values from 107 healthy Caucasian men and women over the age of 65 years old (range: 65–89 years) who participated in a separate longitudinal study (Stout et al., 2013) were used for this investigation. Participants were ambulatory individuals that lived in the midwestern United States who did not have any major health limitations, including recent major surgery (within four weeks), current active malignant disease, immunodeficiency disorder, history of diabetes, kidney disease, partial or full artificial limb, uncontrollable hypertension, and recent myocardial infarction (within three months). All subjects had a Geriatric Nutritional Risk Index score of greater than 92 [GNRI = (1.489 × albumin, g/L) + (41.7 × weight / ideal weight)] (Bouillanne et al., 2005), indicating low risk for nutrition-related health complications, which has been positively related to muscle function and potential benefit from nutritional support and physical rehabilitation (Cereda and Vanotti, 2007). This study was approved by a university institutional review board. All participants completed a written informed consent during the original investigation.

2.2. Research design

All participants completed the requisite measurements in a single testing day. Participants were instructed to avoid exercise for at least 24 h prior to testing. Proper hydration status via specific gravity (Usg < 1.030) was determined from a urine sample before the testing session commenced. Following a 12-hour fast (ad libitum water intake was allowed up to 1 h prior to testing), each participant's height, body mass, handgrip strength, and body composition from DXA was measured. BMI, RSMI, and FAT% were then calculated. From the BMI and handgrip strength values, separate prediction equations were developed for FAT% and RSMI. Lastly, previously established cutoff values for obesity and sarcopenia in the elderly were used to develop isoperformance curves. The resulting isoperformance curves were then compared to individual predictor values for BMI and handgrip strength.