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Muscle mass and muscle function over the adult life span: A cross-sectional study in Flemish adults

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ABSTRACT

Background: Aging is accompanied with a progressive deterioration of skeletal muscle mass (SMM) and muscle function, also termed sarcopenia.
Methods: The aim was to describe SMM (based on bioelectrical impedance) and muscle function of the leg extensors over the adult age span in 819 men and 578 women, aged 18–78 years. The distribution of skeletal muscle index (SMI; SMM/height^2) groups was described and muscle force–velocity characteristics were examined between SMI-groups over the adult life span. Subjects were divided into age categories and SMI groups to compare their muscle strength characteristics. Isometric and isokinetic strength, ballistic movement speed and muscular endurance of the knee extensors were evaluated on a Biodex dynamometer.
Results: Age by gender interaction effects were found significant ($P < 0.01$) for all strength tests. In general, the overall drop in slow and faster knee extension strength was larger than the isometric component, with women showing larger losses by the age of 60–70 years compared to men. Regression analysis revealed significant ($P < 0.01$) age-related reductions, with the largest explained variance for the muscular endurance parameter (24%). No age by SMI-group interaction effect was observed for muscle function, but main effects of age and SMI were significant ($P < 0.01$).
Conclusion: The age-related decline in muscle function was stronger in women. Furthermore, a low SMI results in a weaker muscle function compared to a normal SMI in each age-category, pointing out that its relationship with physical disability should therefore be further examined over the adult life-span.

1. Introduction

A normal part of ageing is the progressive deterioration of skeletal muscle mass accompanied by significant decreases in muscle function (strength or performance), a condition also known as sarcopenia (Cruz-Jentoft, Baeyens, Bauer, Boirie, Cederholm, & Landi, 2010). This change in muscle characteristics has significant consequences for the elderly, such as a reduced mobility, a higher risk of fall related injury and impaired quality of life (Campbell, Borrie, & Spears, 1989; Reid, Naumova, Carabello, Phillips, & Fielding, 2008; Rizzoli et al., 2013). Since the Belgian elderly population (≥65 years) is estimated to reach a total of 3,326,205 in 2060 (26.27% of the total population), understanding how muscle characteristics change over adult life span will become a major public health concern (Federaal Planbureau, 2008).

During early life, muscle mass is known to progressively increase until it reaches its peak around the age of 24 years (Deschenes, 2004; Lexell, 1995; Sayer et al., 2008). Afterwards it is maintained quite well throughout the fifth decade with a moderate decline of about 10% (Lexell, 1995; Deschenes, 2004). However, this decline in muscle mass accelerates over the age of fifty leading to an annual decrease up to 1.4% (Deschenes, 2004; Lang et al., 2010; Mitchell et al., 2012; von Haehling, Morley, & Anker, 2010). In total, a reduction of approximately 40% in muscle mass and a decline in cross-sectional area of ~20% can be seen by the age of eighty (Deschenes, 2004; Evans, 2010). These changes in muscle mass have been confirmed by numerous studies (Frontera et al., 2000; Hughes et al., 2001; Janssen, Heymsfield, Wang, & Ross, 2000b).

At present, several methods are available to evaluate muscle mass, however most of them are sophisticated imaging techniques such as computerized tomography (CT) and magnetic resonance imaging (MRI). An inexpensive, non-invasive and reliable alternative is bio-electrical impedance analysis (BIA). This technique is sufficiently accurate to determine human body

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composition, and it is in this regard that Janssen, Heymsfield, Baumgartner, and Ross (2000a) developed and validated a regression equation to predict skeletal muscle mass (SMM). Using this equation they attempted to determine skeletal muscle cutpoints for identifying elevated physical disability risk in older adults (Janssen, Baumgartner, Ross, Rosenberg, & Roubenoff, 2004).

In 4499 elderly subjects (≥60 years), physical disability was assessed using a questionnaire and skeletal muscle mass was determined by BIA. Absolute muscle mass (kg) was then normalized for height (m) and defined as the skeletal muscle index (SMI, kg/m^2). In women, the SMI cutpoints were 5.76–6.75 and ≤5.75 kg/m^2 for moderate and high physical disability risk, respectively. Higher cutpoints were found in men, with values of 8.51–10.75 and ≤8.50 kg/m^2 (Janssen et al., 2004). The likelihood of physical disability was increased if SMI values were lower than these cutpoints. Similar studies have been performed previously to associate sarcopenia with physical disability, although they did not consider the relation between skeletal muscle mass and physical disability (Baumgartner et al., 1998; Janssen, Heymsfield, & Ross, 2002; Melton et al., 2000).

It is well known that advancing age also has an impact on muscle function. This is the action generating capacity of the muscle mass, therefore referring to muscle strength and muscle power. However, despite the fact that it is generally accepted that the age-related loss of muscle mass is the primary cause of this loss in muscle function, there appears to be a discrepancy between the two. The age-related change in muscle function is more pronounced than the change in muscle mass. For muscle strength, a loss becomes apparent after the age of fifty years. From thereon annual decreases of about 1.5% per year are reported between the ages of 50 and 60 years. After the sixth decade, declines even increase amounting up to 3% per year (Baumgartner et al., 1998). The largest decrease, however, is observed for the age-related change in muscle power (work done per unit time). Its onset can be observed at the age of 40 years and power is thereafter reduced with 3–4% per year (Melton et al., 2000).

The aim of the current study was to describe muscle mass and muscle force–velocity characteristics of the leg extensors during the adult life span and compare them between males and females. It was our hypothesis that a decrease in muscle mass and muscle function would become more apparent with advancing age, and earlier and larger in women compared to men. Since SMI has been linked with physical disability, a description of the distribution in Skeletal Muscle Index-groups was made across the entire adult life span in Flemish adults. Furthermore, muscle force–velocity characteristics were examined between SMI-groups over the adult life span, where it was expected that a low or poor SMI would result in lower muscle function and that lower SMI groups would show a faster decrease compared to the normal SMI group with ageing.

2. Methods

2.1. Subjects

Data for this study were gathered in the framework of the first generation Flemish Policy Research Centre Sport, Physical Activity and Health (SPAH) between October 2002 and April 2004. The purpose of this cross-sectional survey was to examine the relationship between physical activity, physical fitness and several health parameters in a randomly selected community sample of 18- to 80-year-old subjects in Flanders, Belgium (Wijndaele et al., 2007). Subjects were asked to visit the SPAH examination center to go through a medical examination, anthropometric measurements, physical tests, and a number of physical activity and health-related questionnaires. Subjects were excluded in the event of a cardiovascular disease (aortic valve stenosis, mitral insufficiency, abnormal heart auscultation or electrocardiogram; systolic blood pressure >160 mm Hg and/or diastolic blood pressure >100 mm Hg; sudden death of father or brother before the age of 45, or of mother or sister before the age of 55), acute thrombosis, recent surgery, neurodegenerative or neuromuscular disease, infection or fever, diabetes or pregnancy. In the current study, results are based on data of 819 men and 578 women, aged 18–78, of Flemish Caucasian origin. Prior to participation, study purpose and procedures were explained and subjects gave their written informed consent. Ethical approval for this study was provided by the Medical Ethics Committee of the KU Leuven. Research was conducted in consensus with the Helsinki Declaration.

2.2. Outcome measurements

The measurements performed in the current longitudinal study have been previously described elsewhere (Wijndaele et al., 2007). A concise overview is presented here below and supplemented where necessary.

2.2.1. Anthropometry

Anthropometric measurements were completed by trained staff using standardized techniques and equipment. All subjects were barefoot and wore minimal clothing. Height was measured to the nearest millimeter using a Holtain stadiometer (Holtain, Crymych, UK) and weight was measured to the nearest 0.1 kg using a digital scale (Seca 841, Seca GmbH, Hamburg, Germany). Body Mass Index (BMI) was calculated as [weight (kg)/(height (m))^2].

2.2.2. Body composition

Percentage body fat (%BF) was obtained by performing a bio-electrical impedance analysis (BIA) according to standardized procedures. Fat mass (FM, kg) and fat free mass (FFM, kg) were calculated for each subject based on the %BF.

2.2.3. Skeletal muscle mass

The following BIA equation of Janssen et al. (2000a) was used to calculate whole-body skeletal muscle mass (SMM):

$$\text{SMM (kg)} = \left[\left(\frac{\text{height}^2}{\text{BIA} - \text{resistance} \times 0.401}\right) + (\text{gender} \times 3.825) + (\text{age} \times -0.071)\right] + 5.102$$

where height is in cm; BIA-resistance is in ohms; for gender, men = 1 and women = 0; and age is in years. Janssen et al. (2000a) developed and cross-validated this equation against magnetic resonance imaging measures of whole-body-muscle mass in a sample of 388 men and women varying widely in age (18–86 years) and adiposity (BMI = 16–48 kg/m^2).

Absolute skeletal muscle mass (kg) was converted to a measure of relative muscle mass, termed skeletal muscle index (SMI), as follows:

$$\text{SMI (kg/m}^2) = \frac{\text{SMM (kg)}}{\text{height}^2\,(\text{m}^2)}$$

This way, differences in SMM associated with inter-individual variation in height will be eliminated by the square of height in the denominator of the SMI.

2.2.4. Muscle performance

2.2.4.1. Handgrip strength and upper limb muscle quality. Handgrip strength (HGR) was determined using a hydraulic handgrip