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The relationship between muscle quality and incidence of falls in older community-dwelling women: An 18-month follow-up study

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ABSTRACT

Introduction: Important components that might mediate the relationship between aging and falls are reduced muscle strength and mass. Although muscle-related phenotypes have been linked to falls in older people, the role of muscle quality has yet to be examined.

Aim: To investigate the relationship between muscle quality and incidence of falls over an 18-month follow-up in older community-dwelling women.

Methods: A total of 167 women (68.1 ± 6.2 years) underwent quadriceps isometric peak torque and thigh-muscle thickness assessments using isokinetic dynamometer and ultrasound, respectively. Muscle quality was considered as the ratio between maximal strength and muscle thickness. Participants were tracked by phone calls for ascertainment of falls during the follow-up period. Cox proportional regressions and X^2 tests were performed, with statistical significance set at $P < 0.05$.

Results: A total of 139 volunteers were successful tracked over the follow-up period. The overall incidence of fall was 23.4% (95% CI: 16.5–31.0). Rate of fallers among individuals with low-muscle quality (57.7%) was higher than in those with normal muscle quality (15.3%) ($X^2 = 21.132$; $P < 0.001$). The proportion of multiple fallers was also significantly higher ($X^2 = 11.029$; $P < 0.001$) among volunteers with low-muscle quality when compared to those with normal muscle quality (14.8% and 3.6%, respectively). The presence of low-muscle quality was associated with a significantly greater risk of falls over the follow-up (hazard ratio: 4.619; 95% CI: 2.302–9.269).

Conclusion: Low-muscle quality is associated with a higher incidence of falls in older women. These findings provide support for the concept that muscle quality is a clinically meaningful assessment among older people.

1. Introduction

Falls events comprise a geriatric syndrome (Inouye et al., 2007) that has been considered the leading cause of hospitalization and accidental death among aged people (Fuller, 2000; Gelbard et al., 2014). Thus, falls are deemed as a major public health issue that imposes an important economic burden on health care costs (Perracini and Ramos, 2002; PicciniI et al., 2007). In the United States, a recent estimate of falls-related annual health care costs pointed to approximately $50 billion (Florence et al., 2018). Important components that might mediate the relationship between aging and falls are reduced muscle strength and mass (Balogun et al., 2018; Bento et al., 2010; Hairi et al., 2010; Newman et al., 2006). However, although the loss of muscle mass is associated with the decline in strength during aging, this decline in strength is much more rapid than the loss in muscle mass (Frontera et al., 2000; Goodpaster et al., 2008). Furthermore, a growing body of evidence has emerged demonstrating that strength has a better prognostic value compared to muscle mass to predict worsening disability (Menant et al., 2017; Pisciottano et al., 2014) and falls incidence among older individuals (Schaap et al., 2017).

In fact, muscle strength has been recognized as a determinant of risk of falls and thus its evaluation has been especially emphasized in older people (Francis et al., 2017; Pijnappels et al., 2008; Schaap et al., 2017; Silva Neto et al., 2012). In addition, it has been postulated that the contractile function of the skeletal muscle is reduced in older fallers when compared to non-fallers (Pijnappels et al., 2008; Skelton et al., 2002). Nevertheless, a recent report (Abe et al., 2016) demonstrated that absolute strength is not the best predictor of physical performance in older people. As an alternative to minimize some gaps in the association between strength and muscle mass with falls-related outcomes, the combination of these variables can provide important information in the predictions falls events (Gadelha et al., 2018a). In this scenario, the term "muscle quality" has been introduced to refer to the relationship between muscle strength and muscle volume (Gadelha et al.,

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2018a; Pinto et al., 2014; Rolland et al., 2004). The widely used index of muscle quality is the force produced per unit of active muscle mass (Gadelha et al., 2018a; Pinto et al., 2014), which can be expressed by the ratio between strength and muscle mass (Gadelha et al., 2018a; Pinto et al., 2014).

Previous reports have highlighted the relevance of muscle quality, rather than muscle strength or mass separately, in assessing muscle performance in the elderly (Abe et al., 2016; Pinto et al., 2014). Thus, muscle quality has been thought as a promising measure when examining muscle-related phenotypes relationships with clinical outcomes in older people. A recent cross-sectional study (Gadelha et al., 2018a) demonstrated that muscle quality was negatively associated with dynamic balance, fear of falling, and previous falls in older women. However, no prospective data exists in terms of the relationship between muscle quality and falls. The aim of the present study was to investigate the relationship between muscle quality and incidence of falls over 18-month follow-up in older community-dwelling women.

2. Materials and methods

2.1. Subjects

Two hundred and forty-six typical community-dwelling older women were recruited through flyers, phone calls, e-marketing, and visits to centers of leisure and physical activity for elderly people. Eligible criteria were as follows: to voluntarily participate in the present study, to walk without assistance, and to be aged between 60 and 85 years old. All volunteers answered a face to face questionnaire addressing medical history, medication use, and co-morbidities. The mini-mental state examination (MMSE) and the Katz index were also used to verify that none of the volunteers exhibited cognitive impairments or functional dependency, respectively. In this regard, the cut-off points for MMSE considered the level of schooling, being 13, 18, and 26 for illiterates, up to 8 years of schooling, and > 8 years of schooling, respectively. Moreover, the adopted cut-off for Katz index was 6 points, which represents functional independence. Physical activity level was evaluated using the short version of the International Physical Activity Questionnaire – IPAQ (Craig et al., 2003). Exclusion criteria were as follows: musculoskeletal or neurological disorders, vestibulopathy, diabetes, cancer, lower limbs prosthesis, postoperative condition, and dominant lower limb pain that hinders strength ratings. After exclusion criteria were applied, a total of 167 women took part in the baseline analysis, and then 139 were successfully followed up.

All subjects were weighed on a digital scale to the nearest 50 g (Lider®, P150M, São Paulo, Brazil) and height was measured with a wall stadiometer (Sanny®, São Paulo, Brazil). Body mass index was calculated by dividing body weight by the square of the height (kg/m^2) of the volunteers.

All volunteers were informed about the study procedures and voluntarily signed an informed consent form. All experiments on human subjects were conducted in accordance with the Declaration of Helsinki and the study protocol was previously approved by the Institutional Review Board (1.2223.636).

2.2. Muscle thickness

Thigh muscle thickness was evaluated by ultrasonography (Philips, Lagoa Santa, MG, Brazil). Water-soluble gel was applied at the site of measurement and a 7.5-MHz transducer was positioned perpendicularly to the muscle analyzed. The reference point for the ultrasound transducer placement was two-thirds from the distance between the great trochanter to the lateral epicondyle, and 3 cm lateral to the midline of the anterior thigh (Chilibeck et al., 2004). All measures were conducted considering the dominant lower-limb of each participant. The transducer was held by the hand of the examiner at a distance of 30 cm from its base and no additional pressure was applied to standardize the compression generated on the skin. Once the examiner found a satisfactory image, it was frozen and stored. Noteworthy, the use of ultrasound has been previously validated as a noninvasive imaging biomarker of frailty in elderly adults (Mirón Mombiela et al., 2017). All measurements were performed three times by the same trained examiner, and another inspector independently calculated the distance in millimeters from the mean value of three images. The muscle thickness test–retest reliability coefficient for our laboratory was 0.94, which was close to those presented elsewhere (≥ 0.85) (Radaelli et al., 2014).

2.3. Isometric peak torque

Dominant peak torque (PT) of the knee extensors was measured by an isokinetic dynamometer (Biodex 4, Biodex Medical, Inc., Shirley, NY, USA). After a warm-up involving two sub-maximal sets of 10 and 6 repetitions, respectively, the testing protocol consisted of 2 sets of 4 s maximal isometric contractions at 60° of knee flexion. It is important to note that 60-degree knee flexion angle represents the point of maximum attainable isometric torque during measurements of quadriceps muscle strength (Baum et al., 2016; Knapik et al., 1983).The recorded value was the single muscle contraction that elicited the highest PT throughout the protocol, which was expressed in Nm. After a full explanation of the procedures, participants were seated on the dynamometer which was then carefully adjusted. The rotation axis of the dynamometer arm was oriented with the lateral condyle of participant's dominant femur. Both arms were positioned crossed over the chest and velcro belts were used at the trunk, pelvis, and thigh to avoid possible compensatory movements. Participants were asked to perform the movement with their maximal strength while verbal encouragement was offered. Calibration of the equipment was performed according to the manufacturer's specifications before every testing session. The test-retest reliability coefficient for knee extensors isometric peak torque was reported to be 0.88 (Alvares et al., 2015).

2.4. Muscle quality

Muscle quality was expressed as force per unit of muscle mass and was calculated by dividing the isometric PT of knee extensors by the thigh muscle thickness of the same limb (Gadelha et al., 2018a). Thus, muscle quality was assessed according to the following equation:

$$\text{Muscle quality } (\text{Nm}\cdot\text{mm}^{-1}) = \text{Strength (Nm)/Muscle thickness (mm)}.$$

According to specifications previously described, the cut-off value adopted for identify low-muscle quality was $\leq 3.6\ \text{Nm}\cdot\text{mm}^{-1}$ (Gadelha et al., 2018a).

2.5. Ascertainment of falls

Despite of the primary outcome was the incidence of falls, other falls-related variables as number of falls, falls-induced fractures, and falls-induced hospitalization were also investigated as secondary outcomes. Outcomes were recorded through semi structured telephone calls, in which survey was conducted at the end of the 18-month follow-up. This approach has been previously applied in a variety of prospective epidemiological studies, and has been shown to be reliable and sensitive to detect outcomes, including falls (Barry et al., 2014; Bernal et al., 2017; Himes and Reynolds, 2012; Mitchell et al., 2014; Ylitalo and Karvonen-Gutierrez, 2016). During the semi structured interviews, participants were asked about any falls incident, defined as an unexpected event in which participants come to rest on the ground, floor, or other lower level. For each fall event reported, participants described the situation in maximum details. Specific information of interest included date of fall, participant description of how the fall occurred, consequences and injuries, and hospital admission. Also, falls events were categorized into internal or external, being the first characterized

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