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Muscle quality is associated with dynamic balance, fear of falling, and falls in older women

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1. Introduction

Falling is one of the main causes of injury, fractures, and potential reason of disability in the elderly (Bento et al., 2010; Fuller, 2000; Gelbard et al., 2014; Perracini and Ramos, 2002). Falls events comprise a geriatric syndrome (Inouye et al., 2007) that has been considered the leading cause of hospitalization and accidental death among older 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; PiccinilI et al., 2007). While the causes of falling in the elderly are multifactorial, it is well documented that contributing factors encompass fear of falling, reduced balance, muscle weakness, and previous falls events (Pluijm et al., 2006; Ueno et al., 2006). Of note, it has been postulated that women are more susceptible to falls-related outcomes (Newman et al., 2003; PiccinilI et al., 2007; Visser et al., 2005), since they present lower skeletal muscle mass and strength over the lifespan when compared to men (Cruz-Jentoft et al., 2010; Newman et al., 2003).

Balance control is pivotal for postural equilibrium and its preservation is critically important for reducing the risk of falls with aging (Avelar et al., 2016). Maintaining postural balance requires integration of sensory input, central processing, and appropriate musculoskeletal recruitment in order to perceive stimuli and react. Balance can be dynamically and statically evaluated using the Timed Up-and-Go (TUG) and posturography, respectively. It has been argued that the TUG test reflects balance quality given the fact that it comprises motor tasks demanding complex postural control, and is currently recommended by the American and British Geriatrics Societies for fall-risk assessment (Kenny et al., 2011). An essential biomechanical pathway to maintaining postural stability involves the control of the body center of pressure (CoP). Posturography assessment using measures of CoP recorded by a force plate has been shown to provide important information, with increased CoP sway indicating predisposition to falls (Piirtola and Era, 2006). Another important factor that might mediate the relationship between aging and falls is the fear of falling, which has been shown to be increased in older adults (Friedman et al., 2002; Lopes et al., 2009). In addition, age-related muscle weakness has been also investigated in this field (Bento et al., 2010; Moreland et al., 2004; Pijnappels et al., 2008; Skelton et al., 2002).

Moreland et al. (2004) demonstrated an association between muscle weakness and significantly higher risk of falls in older people. Moreover, muscle strength, particularly of the lower limbs, was an important factor in the assessment and treatment for older people at risk of falling. In fact, it has been postulated that the contractile function of skeletal muscle is reduced in older fallers when compared to non-fallers (Pijnappels et al., 2008; Skelton et al., 2002). Muscle strength has been recognized as a determinant of both postural balance and risk of falls and its evaluation has been especially emphasized in older people (Francis et al., 2017; Pijnappels et al., 2008; Silva Neto et al., 2012). In this regard, isokinetic testing has become a gold standard method to assess muscle strength in both clinical and research settings (Brown and Weir, 2001; Pinto et al., 2012). Nevertheless, a recent report (Abe et al., 2016) demonstrated that absolute strength is not a good indicator of physical performance in older people. Although the loss of muscle mass is associated with the decline in strength during aging, this strength decline is much more rapid than the loss in muscle mass, indicating a reduction in muscle quality (Frontera et al., 2000; Goodpaster et al., 2008). Numerous scientists have used the term “muscle quality” to refer to the relationship between muscle strength and muscle volume (Pinto et al., 2014; Rolland et al., 2004). In particular, muscle quality has been

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described as the force produced per unit of active muscle mass (Pinto et al., 2014) and can be assessed by the ratio between strength and muscle mass (i.e., specific torque) (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 (Pinto et al., 2014). Thus, muscle quality has been introduced as a promising measure when examining muscle-related phenotypes relationships with clinical outcomes in older people. However, no previous investigations have examined the association between muscle quality and falls-related risk factors in older women. Therefore, the aim of the present study was to investigate the association between muscle quality, balance, fear of falling and previous falls in older women.

2. Materials and methods

2.1. Participants

Approximately 500 volunteers were recruited through flyers, phone calls, e-marketing, and visits to centers of leisure and physical activity for elderly people. Eligibility 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. From this initial recruitment, 246 community-dwelling women (68.1 ± 6.2 years) were eligible for the present cross-sectional study. All volunteers answered a face to face questionnaire addressing medical history, medication use, and comorbidities. 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. 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 older women took part in the present analyses. All subjects were weighed on a digital scale to the nearest 50 g (Lider®, P150M, São Paulo, Brasil) and height was measured with a wall stadiometer (Sanny®, São Paulo, Brasil). 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. Of note, 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 was 0.94.

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). All measurements were carried out by two trained technicians. 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 degree of knee flexion. 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. Test-retest reliability coefficient value for knee extensor peak torque was 0.91 in our laboratory.

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 high muscle thickness of the same limb. Thus, muscle quality was assessed according to the following equation:

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

Of note, muscle quality quintiles were created. According to specifications previously described (Hairi et al., 2010), subjects in the lowest quintile of muscle quality ($\leq 3.6\ \text{Nm}\cdot\text{mm}^{-1}$) were considered as having low-muscle quality, while those in the remaining quintiles were considered as having normal-muscle quality.

2.5. Static posturography

Static posturography was measured using a force plate (AccuSway Plus, AMTI, Watertown, United States), which measures displacements of center of pressure (CoP). The force plate signals were sampled at 100 Hz and data were filtered using 10 Hz low-pass cutoff frequency. The software AMTI Balance Clinic was used for signal recording. The reliability coefficient was described elsewhere ($r \geq 0.75$). To quantify the postural stability, CoP mean speed and the range of CoP displacement along anteroposterior (AP) and mediolateral (ML) axes were recorded. The mean speed of the CoP corresponds to the cumulative distance over the sampling period. The range of the CoP displacement represents the difference between the maximum and minimum values of the CoP along the AP and ML axes.

Subjects performed two experimental conditions: feet together/eyes open (FTEO) and feet together/eyes closed (FTEC). Participants were asked to keep their sight fixed at a mark on the wall, positioned 2.0 m away from the plate and 1.5 m above floor level, and to breathe normally. Participants were on barefoot and were instructed to stand for 30 s on the force plate, with arms relaxed and with minimal body sway. They performed three trials for each condition, in a random order.

2.6. Dynamic balance

Dynamic balance was measured using TUG (Mathias et al., 1986). Procedures were fully explained before assessment followed by a familiarization attempt. In brief, volunteers were individually seated in a standard chair with 45 cm of height, with the back against the chair,