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Original Research

Can the calf-raise senior test predict functional fitness in elderly people? A validation study using electromyography, kinematics and strength tests

Helô-Isa André [a, b, *], Filomena Carnide [a, b], Andreia Moço [b], Maria-João Valamatos [a, b], Fátima Ramalho [a, c], Rita Santos-Rocha [a, c], António Veloso [a, b]

[a] Centro Interdisciplinar para o Estudo da Performance Humana, Faculdade de Motricidade Humana, Cruz Quebrada, Portugal
[b] Universidade de Lisboa, Faculdade de Motricidade Humana, Departamento de Desporto e Saúde. Laboratório de Biomecânica e Morfologia Funcional, Cruz Quebrada, Portugal
[c] Instituto Politécnico de Santarém, Escola Superior de Desporto de Rio Maior, Rio Maior, Portugal

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ABSTRACT

The assessment of the plantar-flexors muscle strength in older adults (OA) is of the utmost importance since they are strongly associated with the performance of fundamental tasks of daily life.

The objective was to strengthen the validity of the Calf-Raise-Senior (CRS) test by assessing the biomechanical movement pattern of calf muscles in OA with different levels of functional fitness (FF) and physical activity (PA).

Twenty-six OA were assessed with CRS, a FF battery, accelerometry, strength tests, kinematics and electromyography (EMG). OA with the best and worst CRS scores were compared. The association between the scores and EMG pattern of ankle muscles was determined.

OA with the best CRS scores presented higher levels of FF, PA, strength, power, speed and range of movement, and a more efficient movement pattern during the test. Subjects who scored more at the CRS test demonstrated the possibility to use a stretch-shortening cycle type of action in the PF muscles to increase power during the movements.

OA with different levels of FF can be stratified by the muscular activation pattern of the calf muscles and the scores in CRS test. This study reinforced the validity of CRS for evaluating ankle strength and power in OA.

1. Introduction

Lower limbs' strength is recognized as a strong predictor of functional limitations in community-dwelling elderly (Foldvari et al., 2000; Gross, Stevenson, Charette, Pyka, & Marcus, 1998; Hyatt, Whitelaw, Bhat, Scott, & Maxwell, 1990). Maximal or average strength can be important for the functional performance of older adults (Bassey et al., 1992; Fukagawa, Wolfson, Judge, Whipple, & King, 1995; Rantanen, Guralnik, Ferrucci, Leveille, & Fried, 1999). Nevertheless, power has shown evidence of being even more significant in predicting the limitations in mobility and consequent functional disability of the elderly (Puthoff & Nielsen, 2007; Skelton, Kennedy, & Rutherford, 2002; Suzuki, Bean, & Fielding, 2001).

The ankle muscles are critical to the performance of a large number of daily living activities, such as, walking (Ishikawa, Komi, Grey, Lepola, & Bruggemann, 2005), stair climbing (Reeves, Spanjaard, Mohagheghi, Baltzopoulos, & Maganaris, 2009), and chair rising (Gross et al., 1998). The ability to perform these activities are strongly associated with plantar-flexor (PF) muscle power (Suzuki et al., 2001).

Longitudinal studies have shown that during the aging the strength suffers a progressive decrease in the order of 3–4% per year in men, and 2.5–3% per year in women after 75 years of age (Mitchell et al., 2015). The plantar-flexor muscles are those which

* Corresponding author. Faculdade de Motricidade Humana, Universidade de Lisboa, Estrada da Costa, 1499-002, Cruz Quebrada, Dafundo, Portugal.

E-mail addresses: heloandre@fmh.ulisboa.pt (H.-I. André), fcarnide@fmh.ulisboa.pt (F. Carnide), moco.a.v@gmail.com (A. Moço), mjvalamatos@fmh.ulisboa.pt (M.-J. Valamatos), fatimaramalho@esdrm.ipsantarem.pt (F. Ramalho), ritasantosrocha@esdrm.ipsantarem.pt (R. Santos-Rocha), apveloso@fmh.ulisboa.pt (A. Veloso).

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exhibit a more pronounced age-related decline, with significant reductions of 2.1% per year in females and 2.5% in males (73–97 years) (Winegard, Hicks, Sale, & Vandervoort, 1996). Decline in the plantar-flexors muscle strength has negative impact on the seniors' gait performance (DeVita & Hortobagyi, 2000; Kerrigan, Todd, Della Croce, Lipsitz, & Collins, 1998; Novak & Brouwer, 2011) and it is associated with increased risk of falls in independent elderly (Melzer, Benjuya, & Kaplanski, 2004; Whipple, Wolfson, & Amerman, 1987). Age-related changes in biological systems are more affected by lifestyle conditions than aging itself, and that the rate of atrophy of systems when they are never stressed is much higher than with increasing use (Williams, 1984). It is known that age is responsible for only 30% of strength variation, while disuse and reduction in muscle stimulation are responsible for the rest of the variation (Lindle et al., 1997; Rantanen & Heikkinen, 1998). Thus, measurement of strength levels may yield important information that can be used in proactive approaches to prevention of functional decline in the elderly (Rikli & Jones, 1999).

The Calf Raise Senior (CRS) test (André et al., 2016) has recently been proposed with the objective of assessing the plantar-flexors' strength and power in the elderly population. Based on the Calf-raise (Heel-rise) test (Hebert-Losier, Newsham-West, Schneiders, & Sullivan, 2009), this test was adapted to be administered in groups of seniors with a wide range of functional fitness and physical activity. The CRS provides a standardized test protocol which involves bilateral movements of lifting/lowering the heels, at the greatest possible speed, being the final result the correct number of repetitions performed in 30 s. CRS test showed to have a very good construct and criterion validity, demonstrating strong positive associations with strength assessments, physical activity level and a negative correlation with age. The test also presented an excellent test-retest reliability (ICC = 0.90, SEM = 2.0) and inter-rater (ICC = 0.93-0.96), along with a good intra-rater reliability (ICC = 0.79–0.84) (André et al., 2016).

Although these properties, it seems relevant to verify if CRS is sensitive to detect differences in ankle muscles movement pattern among older adults with different functional fitness profiles.

Thus, the purposes of this study were to strengthen the validity of the CRS test and to determine whether the biomechanical movement pattern would be different from older adults with high/low and major/minor strength levels functional capacities.

2. Methods

2.1. Participants

A convenience sample of twenty-nine elderly participants (50% women) was recruited from day care centers, senior schools, fitness clubs and community exercise programs. A post-hoc power analysis indicated that a total sample of 10 people would be needed to detect large effects (d = 0.80) with 90% power using a *t*-test between means from results of previous study (André et al., 2016) with alpha at 0.05. The participant's mean age was 73.7 years (SD = 7.1); and their mean body mass index was 25.3 kg/m^2 (SD = 2.79). All participants agreed to participate voluntarily in the study and gave their written informed consent according to the protocols approved by the Ethical Committee of the Faculty of Human Kinetics – University of Lisbon.

Eligibility criteria were: age of 65 and over, community-dwelling and having locomotor autonomy. The exclusion criteria included: neurologic or cardiovascular diagnosed conditions; any previous history of fractures or surgery involving the lower limbs within the previous 12 months; use of a walking aid, hip, knee or ankle prosthesis and pain-free or any discomfort in the lower limbs during the test protocols.

2.2. Study design

The validation process included three phases: 1st) Demographic and self-perception of health status were collected through questionnaires (Valente, 2013), weight and height (Marfell-Jones, Stewart, & de Ridder, 2012; Norton et al., 1996), along with functional fitness tests and the CRS test for familiarization; 2nd) After 3 days the CRS test was again evaluated, together with kinematic (KIN) and electromyography (EMG) protocols. After a rest period, the participants performed the strength tests in an isokinetic dynamometer for familiarization; 3rd) One week later the same strength assessment procedures were repeated together with the EMG.

2.3. Physical activity (PA)

PA was assessed through uniaxial accelerometers (Actigraph GT1M model - Manufacturing Technology Inc., FL, USA) during 5 consecutive days between the 2nd and 3rd phases. Data were recorded with epochs of 1 min and analyzed using the cut-offs established by Freedson (Freedson, Melanson, & Sirard, 1998). The complete procedures are described elsewhere (André et al., 2016).

2.4. Functional fitness (FF)

The FF was assessed by experienced and trained examiners who administered the following tests: A) "30 s Chair-stand" (CS), "Eight-foot Up & Go" (UG), and the "2-min-step" (2-min), from the "Senior Fitness Test" battery (SFT) (Rikli & Jones, 1999), which aimed to assess the strength in the lower limbs, agility, coordination, and cardiorespiratory fitness, and; B) "Step up and over" and "Tandem walk" tests to evaluate the dynamic balance; and "Stand on one leg" and "Stand on foam eyes closed" tests to assess static balance, from the "Fullerton Advanced Balance Scale" (Rose, Lucchese, & Wiersma, 2006). The selection of these tests was based on its ability to accurately predict functional decline associated with aging (Hernandez and Rose, 2008; Rose et al., 2002). The variable "Total Functional Fitness Score" (TFFS) was then calculated by summing all FF variables after normalization by gender and age and converting the continuous variables into ordinal variables, according to the procedures referred to elsewhere (Moniz-Pereira, Carnide, Machado, André, & Veloso, 2012).

2.5. Strength assessment

The maximum voluntary contraction (MVC) of plantar-flexor muscles of the leading foot was assessed isometrically in an isokinetic dynamometer BiodexSystem3 (Biodexcorporation, Shirley, NY, USA). The strength testing protocol is fully explained elsewhere (André et al., 2016). In brief, the participants were positioned on the equipment in a sitting position with the hip flexed at 85° (supine position = 0°), and the knee at the maximum extension possible, according to each participant's flexibility limitations. The lateral malleolus was aligned with the rotational axis of the dynamometer, and the ankle was set at a neutral position (0°). The participants were instructed to perform three rapid plantar-flexion MVCs and to maintain this maximal effort for 3 s. Two minutes' rest was allowed between contractions to prevent fatigue. The torque signals were A/D converted (MP100 – Biopac™ Systems, 16bits) with a sample rate of 100 Hz. Acqknowledge (Biopac Systems Inc.) and MATLAB R2011 (The Mathworks, MA, USA) softwares were used for data processing and analyses. Maximal isometric (MISM) torque and rate of force development (RFD) were obtained from the torque signal. The MISM torque (N.m) was considered as the highest torque value across the three MVC curves, and the RFD ($N.s^{-1}$) the greater slope of the MVC curve.