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Short report

Force-velocity profiling in older adults: An adequate tool for the management of functional trajectories with aging☆

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ABSTRACT

Introduction: The actual mechanisms leading to a reduced muscle power and functional ability in older adults are poorly understood. We investigated the association between different force-velocity (F-V) profiles and impaired muscle power, physical and cognitive function, frailty, and health-related quality of life (HRQoL) in older people.

Methods: Physical function (habitual gait speed, timed up-and-go test, sit-to-stand and stair-climbing ability), cognitive function, HRQoL and frailty were evaluated in 31 older subjects (70–85 years). The F-V relationship and maximal muscle power (P_{max}) were assessed in the leg press exercise. The skeletal muscle index (SMI) and fat index, moderate-to-vigorous physical activity (MVPA) and sedentary time were obtained from DXA scans and accelerometry, respectively.

Results: While some subjects showed a force deficit (F_{DEF}), others presented a velocity deficit (V_{DEF}), both leading to an impaired muscle power [Effect size (ES) = 1.30–1.44], and to a likely-very likely moderate harmful effect in their physical and cognitive function, HRQoL and frailty levels (except the V_{DEF} group for cognitive function) [ES = 0.76–1.05]. Leg muscle mass and specific force were similarly associated with force at P_{max}, while MVPA but not sedentary time was related to fat index, force at P_{max}, and power values (all $p < 0.05$). A trend was found for the negative association between fat index and relative P_{max} ($p = 0.075$).

Conclusion: Older subjects exhibited different mechanisms (force vs. velocity deficits) leading to impaired muscle power. Both deficits were associated with a lower physical function and quality of life, and a higher frailty, whereas only a force deficit was associated with a lower cognitive function. Interventions aimed at reversing age- and/or disuse-related impairments of muscle power might evaluate the specific responsible mechanism and act accordingly.

1. Introduction

An impairment in a body structure and/or function can lead to activity limitations and participation restrictions, and depending on their severity could lead to decreased functional ability and disability (WHO, 2013). The neuromuscular system has a major influence on functional ability during aging (Aagaard et al., 2010), and impaired muscle power is considered the most important neuromuscular outcome associated with functional limitations and disability in older subjects (Byrne et al., 2016). High-intensity resistance training has been shown to be superior to other interventions in achieving strength gains in older adults (Caserotti et al., 2008; Csapo and Alegre, 2016), but no evidence exists on the specific exercise intensity eliciting an optimal gain in muscle power (de Vos et al., 2005; Reid et al., 2015). Since muscle power is defined as the product of force and velocity, muscle power testing by means of force-velocity (F-V) profiling (Morin and Samozino, 2016)

Abbreviations: 1RM, one repetition maximum; BMI, body mass index; CL, confidence limit; ES, effect size; F_0, force-intercept; F-V, force-velocity; F_{DEF}, force-deficit group; HGS, habitual gait speed; HRQoL, health-related quality of life; HRQoLsco, health-related quality of life score; MMSE, mini-mental state examination; MVPA, moderate-to-vigorous physical activity; N_{DEF}, non-deficit group; P_{max}, maximal muscle power; PF_{sco}, physical function score; SMI, skeletal muscle index; SPPB, short physical performance battery; V_0, velocity-intercept; VDEF, velocity-deficit group

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might be a more advantageous approach in comparison with the traditional procedures reported in the literature (for a review see Alcazar et al. (2017a)). The F-V relationship is reduced with aging, with some discrepancies between studies in terms of the relative influence that the force and velocity components have on this decrement (Raj et al., 2010). It might be possible that some older adults present a deficit in their force capacity while their velocity component is preserved, and vice versa. In addition, functional ability might be differently affected in older subjects with a deficit in force or velocity (i.e. different F-V profiles). Thus, the main goals of the present investigation were: 1) to assess whether different F-V profiles might lead to an impaired muscle power in older adults; and 2) to evaluate the influence of different F-V profiles (deficit in force vs. deficit in velocity) on physical function, cognitive function, frailty and health-related quality of life (HRQoL).

2. Material and methods

2.1. Participants

Thirty-one older subjects (17 women) met the entry criteria to participate in the study. Subjects were recruited through advertisements and community newsletters. Participants were screened if they were aged ≥70 years, community-dwelling, and reported no participation in a regular exercise training program in the previous 6 months. Exclusion criteria included a short physical performance battery score < 4 (Guralnik et al., 1994), severe cognitive impairment (mini-mental state examination (MMSE) score < 20) (Folstein et al., 1975), neuromuscular or joint injury, stroke, myocardial infarction or bone fracture in the previous six months, uncontrolled hypertension (> 200/110 mm Hg) or terminal illness. All the subjects gave their written informed consent and the study was performed in accordance with the Helsinki Declaration and approved by the Ethical Committee of the Toledo Hospital.

2.2. Main characteristics

Physical function was evaluated by four different tests: 4-m habitual gait speed (HGS), the five sit-to-stand test, the timed up-and-go test, and a 7-step stair-climbing test. Physical function time values were transformed to velocity units ($m \cdot s^{-1}$), and a physical function score (PF_{sco}) was created using composite z-scores to synthesize the reporting of the results. Each test was performed twice and the best result was chosen for further analysis (except for HGS that the average of both attempts was calculated). All the tests were performed by the same evaluator, and CV values ranged between 4.8 and 5.7%. Cognitive function was evaluated by the MMSE (score 0–30) (Folstein et al., 1975). The frailty syndrome was recorded according to the five criteria proposed by Fried (unintentional weight loss, slowness, weakness, physical inactivity or fatigue) (Fried et al., 2001), and health-related quality of life (HRQoL) was assessed using the EQ-5D-5L questionnaire (Herdman et al., 2011), and reported as a HRQoL score ($HRQoL_{sco}$) using composite z-scores from the two scales that are included in the questionnaire.

2.3. Body composition

A stadiometer and scale device (Seca 711, Seca, Hamburg, Germany) was used to record the height (m), body mass (kg) and body mass index (BMI; $kg \cdot m^{-2}$) of the participants. Whole body and regional body composition was assessed by dual energy X-ray absorptiometry (DXA) (Hologic Series QDR Discovery; Hologic Corp., Bedford, MA, USA) and analyzed using commercially available software (Physician's Viewer; APEX System Software Version 3.1.2., Bedford, MA, USA) (Alegre et al., 2015). The skeletal muscle index (SMI; $kg \cdot m^{-2}$) was used as a marker of sarcopenia (Cruz-Jentoft et al., 2010; Fielding et al., 2011). To account for differences in adiposity levels between participants independently of skeletal muscle mass, a fat index was calculated as the ratio of the whole body fat mass and the height squared ($kg \cdot m^{-2}$).

2.4. Physical activity and sedentary time

Physical activity and sedentary behavior were objectively measured over 7 days by accelerometry (ActiTrainer, Actigraph LLC, USA) as previously reported (Del Pozo-Cruz et al., 2017). The subjects wore the accelerometer on the left side of their hip, and were asked to remove it only during the night hours of sleeping and when taking a bath. The device was initialized to collect data using 1-min epochs. Non-wear time was defined as periods of at least 60 consecutive minutes of zero counts, with allowance for 2 min of counts between zero and 100. Common cut-points were used to class each minute as sedentary behavior (< 100 counts·min^{-1}) and MVPA (≥1952 counts·min^{-1}) (Freedson et al., 1998), with the total time partitioned in proportion to the time spent in these behaviors (% of total wearing time). The minimum wearing time considered acceptable for further analysis was established at 4 days and 8 h per day. Six older subjects did not fulfill the minimum wearing time criteria, and were not considered in the corresponding analyses regarding actigraphy.

2.5. Force-velocity testing

A full description and validation of the F-V and muscle power testing procedure has been published recently (Alcazar et al., 2017b). Briefly, the subjects performed 2 sets of 1 repetition with increasing loads (10-kg increments) starting with 40% of their body mass in the leg press exercise (BH Fitness, Serie TR, Spain) until the one repetition maximum (1RM) was achieved (failure defined as not being able to lift a certain load with two attempts). Range of movement was from 100° and 90° of hip and knee flexion, respectively, to 180° or full knee extension. Mean force and velocity data during the concentric phase of each repetition were recorded by a linear position transducer device (T-Force System, Ergotech, Spain). Repetitions were performed as fast and strongly as possible. The F-V relationship during multi-joint movements has been shown to follow a strong linear regression pattern (Jaric, 2015), thus the highest mean velocity for each load was plotted in a Microsoft Excel® custom-made template (Alcazar et al., 2017b), and a linear regression equation was fitted simultaneously during the F-V evaluation. Resting periods between set were allowed according to the mean velocity exerted in the preceding repetition (> 0.50 $m \cdot s^{-1}$: 60 s; 0.30–0.50 $m \cdot s^{-1}$: 90 s; < 0.30 $m \cdot s^{-1}$: 120 s). Several variables were extracted from the F-V regression equation as previously reported (Alcazar et al., 2017b): force-intercept or maximal force (F_0), velocity-intercept or maximal velocity (V_0), slope of the F-V relationship, and maximal muscle power (P_{max}). As older people have to manage their own body mass in most activities of daily living, F-V measures were also relativized to body mass. This procedure showed a good-to-excellent reliability (ICC: 0.91–0.99, CV: 2.6–5.6%, and SEM%: 3.3–9.2%) (Alcazar et al., 2017b).

2.6. Statistical analysis

All data were examined statistically for normality of distribution with the Shapiro-Wilk's test, and log-transformed in case of a non-uniformity result. Standard descriptive statistics were used for continuous variables and contingency tables for categorical variables. Bivariate linear and quadratic regression analyses were performed to evaluate the magnitude of the relationship of absolute and relative muscle power values with the main outcomes. Three deficit groups according to sex-specific tertiles were created to classify the subjects according to their F-V profiles: no deficits in absolute/relative F_0 or V_0 (N_{DEF}; any possible combination of tertiles 1 and 2 of absolute/relative F_0 and V_0); deficit in absolute/relative F_0 (F_{DEF}; tertile 3 in absolute/relative F_0 and tertiles 1 or 2 in V_0); and deficit in V_0 values (V_{DEF};