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Martin Vigorimeter assesses muscle fatigability in older adults better than the Jamar Dynamometer

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ABSTRACT

Introduction: Muscle fatigability can be measured based on sustained handgrip performance, but different grip strength devices exist and their relationship to frailty remains unclear. We aimed to compare muscle fatigability obtained by Martin Vigorimeter and Jamar Dynamometer in older women across levels of frailty.

Method: 53 community-dwelling women living in Greece (63–100 y), categorized according to tertiles on the Frailty Index score (FI) as: low-frail (FI < 0.19), intermediate-frail (FI 0.19–0.36), and high-frail (FI > 0.36). Fatigue resistance (FR, time for maximal grip strength to decrease to 50% during sustained contraction) was measured with both Martin Vigorimeter and Jamar Dynamometer, and grip work (GW, reflecting the area under the time-force curve) was calculated.

Results: FR, when measured with the Martin Vigorimeter, was approximately double in low-frail (44.3 ± 24.6 s) compared to high-frail participants (23.9 ± 12.7 s, p = 0.011), whereas FR was similar across frailty groups when measured with the Jamar Dynamometer. In logistic regression models, FR (OR = 0.94 [0.90–0.99]) and GW (OR = 0.90 [0.82–0.99]) were significantly related to high frailty when measured with the Martin Vigorimeter but not when measured with Jamar Dynamometer. There is a significantly proportional difference in FR measured with both devices ($R^2 = 0.364$, $p < 0.001$), highlighting that the longer the participant could sustain the FR test, the higher the difference in FR measured with both devices.

Conclusion: Our results suggest that the Martin Vigorimeter is a more appropriate handgrip device compared with the Jamar Dynamometer to assess muscle fatigability for older women across levels of frailty. When measured with the Martin Vigorimeter, high-frail participants show twice the level of fatigability compared to low-frail, whereas no difference was observed when using the Jamar Dynamometer. Older participants might stop the FR test prematurely when using the Jamar Dynamometer, before muscle fatigue is reached, indicating that the Jamar Dynamometer is unable to identify those participants with higher levels of muscle endurance. Martin Vigorimeter assessed muscle fatigability might be a good additional marker to include in frailty tools.

1. Introduction

Frailty has a devastating impact on older people, their family and society (Fried et al., 2004). Recently, Azzopardi et al. (2016) established an extensive list of the available frailty instruments and linked their items to the codes of the International Classification of Functioning, Disability and Health to analyze the overlap and gaps. They showed that self-reported fatigue is a central component in several frailty assessment tools. In these studies, as well as in clinical practice, fatigue is usually measured by a subjective estimation of tiredness by the patient (Azzopardi et al., 2016). This sensation of tiredness may indeed characterize frailty by reflecting depletion of physiological reserve capacity. Even so, muscle fatigability, a reduced tolerance for muscular work may be also an important indicator of frailty (Theou et al., 2008; Zengarini et al., 2015). Remarkably, none of the frailty tools reported in the literature include a direct assessment of muscle fatigability.

Previously (Mets et al., 2004; Bautmans et al., 2007; Bautmans and

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Mets, 2005; Bautmans et al., 2010; Bautmans et al., 2005; Bautmans et al., 2008; Bautmans et al., 2011a; Arnold et al., 2017; Beyer et al., 2011a; Beyer et al., 2012) we have validated a new assessment method for determining muscle fatigability (fatigue resistance, FR): during a rapid and simple test, suitable for bedside evaluation, where patients are instructed to sustain maximal handgrip effort as long as possible, and FR is expressed as the time during which grip strength (GS) drops to 50% of its maximum (Bautmans and Mets, 2005). This FR test also allows the calculation of grip work ($GW = 0.75 * GS_{max} * FR$) (Bautmans et al., 2007) which is a parameter reflecting the work output delivered by the muscles during testing. Our previous work demonstrated that FR and GW are significantly related to dependency for basic activities of daily living, self-perceived fatigue and circulating markers of inflammation within groups of community-dwelling older persons (Bautmans et al., 2007; Beyer et al., 2011b; De Dobbeleer et al., 2017), older nursing home residents (Bautmans et al., 2008), hospitalized geriatric patients (Mets et al., 2004; Bautmans et al., 2005; Beyer et al., 2012; Beyer et al., 2011b; De Dobbeleer et al., 2017) and patients following abdominal surgery (Bautmans et al., 2010).

This FR test has been well validated for the Martin Vigorimeter (KLS Martin Group, Tuttlingen, Germany), a device consisting of a rubber bulb connected via a rubber airtight junction to a manometer. Since this device is comfortable and allows performing a dynamic contraction (the rubber bulb is compressible), it is highly suitable to assess sustained maximal contractions, even in frail and/or ill people. When using the Martin Vigorimeter, FR is highly reproducible in older people with ICC-values between 0.91 and 0.94 and 0.88–0.91 respectively for intra- and inter-observer reliability (Bautmans and Mets, 2005). However, many researchers and clinicians are using more classic devices for GS_{max} evaluation such as the Jamar Dynamometer (Sammons Preston, Rolyon, Bolingbrook, IL) which is designed to measure isometric GS and is characterized by its rigid iron handle. GS_{max} measures obtained by the Martin Vigorimeter have been shown to be well correlated with those obtained with the Jamar Dynamometer (Desrosiers et al., 1995). However, no studies have yet compared whether FR measured by both the Martin Vigorimeter and Jamar Dynamometer differs across levels of frailty. This limits the implementation of the FR test across settings as a clinical indicator of frailty. Therefore, the aim of this study was to compare muscle fatigability values obtained by the Martin Vigorimeter and Jamar Dynamometer, and to evaluate the relationship with the degree of frailty in older women.

2. Method

2.1. Participants

A detailed description of the participants and their recruitment is published elsewhere (Theou et al., 2011). Briefly, 53 community-dwelling women (age range: 63–100 years) who were living in Greece participated. The study was approved by the human ethical research committee of Western University, London Ontario Canada, and all participants provided written informed consent.

2.2. Measurements

Participants did a GS_{max} and a FR handgrip performance test using a Martin Vigorimeter (KLS Martin Group, Tuttlingen, Germany) and Jamar Dynamometer (Sammons Preston, Rolyon, Bolingbrook, IL). To be sure that the order for the devices did not affect the handgrip performance test results, they were applied in a random order for the consecutively tested subjects. The Martin Vigorimeter is provided with 3 different sizes of compressible rubber bulbs, but as recommended by Bautmans and Mets (2005) we used the largest bulb for all participants. The Jamar Dynamometer is a rigid iron handle, which can be adjusted according to the individual's hand size. For all participants GS_{max} and FR were assessed in the second handle position (counting from the handle outward), since this was the most comfortable position for the participant's hand. Supplementary Fig. S1A and S1B shows the set-up for each handgrip device. All tests were performed with the self-reported dominant hand with both devices on the same day, in a random order.

2.2.1. Maximal grip strength, fatigue resistance and grip work

After 2 to 3 practice trials, 3 maximal measurements were performed for each hand with both instruments. The shoulder was adducted and neutrally rotated, elbow flexed at 90°, forearm in a neutral position, and wrist in slight extension (0°–30°). Briefly, participants were asked to squeeze 3 times the large rubber bulb or rigid handle as hard as possible. The inter-trial rest interval was 1 min. The highest score of the 3 attempts was registered as GS_{max} in kPa and kg, respectively for Martin Vigorimeter and Jamar Dynamometer. Afterwards, the participants were asked to squeeze the bulb again or handle as hard as possible, and to maintain this maximal effort as long as possible, under continuously standardized verbal stimulation by the investigator. The time in seconds (s) during which GS dropped to 50% of its maximum was recorded as FR. The researcher verified that the starting GS corresponded to their established GS_{max}. GW, a parameter reflecting the total effort produced during the FR test, represents the physiologic work delivered by the handgrip flexor muscles, corresponding to the area under the strength drop decay curve, when assuming a linear decrease of the GS during the FR test. GW was calculated by multiplying the FR in seconds (s) by 75% of the GS_{max} reported as either kPa or kg (Bautmans et al., 2007). We corrected GW for body mass (GW/body mass in kg) since heavier or more obese participants will have to engage more strength and sustain that effort over time in order to execute daily tasks, such as transfers and carrying or moving objects compared to their lighter or leaner counterparts (Bautmans et al., 2011a).

2.2.2. The Borg scale of perceived exertion (RPE)

Immediately after the FR test the Borg scale was assessed in order to obtain RPE scores. RPE is widely used to reliably monitor and guide physical performance intensity. The women were asked to subjectively rate their level of exertion during the FR test, with both devices, going from 0 = "nothing at all" to 10 = "extremely strong/maximal" (Borg, 1982).

2.2.3. Frailty Index

A Frailty Index was constructed based on the accumulation of deficits approach where a deficit can be any symptom, sign, disease, disability, or laboratory abnormality that accumulates with age and is associated with adverse events (Mitnitski et al., 2001). A detailed description of the FI used in this study is published elsewhere (Theou et al., 2011). Briefly, the FI was derived from 56 measures from 13 domains that were assessed through a health history questionnaire (adapted from Rogers, 2005); performance-based measures were excluded. The number of recorded deficits was divided by the total number of measures (56 measures) to give FI score. The FI does not give a cut-off that identifies someone as frail; rather, it is graded so that the greater the score (closest to 1), the more likely it is that someone is vulnerable to adverse events associated with frailty. The FI predicts declining health, institutionalization, and death, and is validated in both community and institutionalized older adults (Rockwood et al., 2007). Prior studies have shown that the FI, even when different deficits are collected, has remarkably similar measurement properties and substantive results, especially when a minimum of 30 variables are included (Rockwood et al., 2007). In this study, participant scores for the FI were split into tertiles. Various cut-points have been suggested for the Frailty Index. Based on Hoover et al. (2013) the first tertile includes the "non-frail/pre-frail" group, the second tertile includes the "frail and more-frail" groups and the last tertile includes the "most frail" group. Here, as described previously (Theou et al., 2011), terminology was simplified and we defined the lowest FI tertile as "low-