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Reliability and relationships among handgrip strength, leg extensor strength and power, and balance in older men

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ABSTRACT

Purpose: To quantify the reliability of isometric leg extension torque (LE_{MVC}), rate of torque development (LE_{RTD}), isometric handgrip force (HG_{MVC}) and RFD (HG_{RFD}), isokinetic leg extension torque and power at 1.05 $rad \cdot s^{-1}$ and 3.14 $rad \cdot s^{-1}$; and explore relationships among strength, power, and balance in older men.
Methods: Sixteen older men completed 3 isometric handgrips, 3 isometric leg extensions, and 3 isokinetic leg extensions at 1.05 $rad \cdot s^{-1}$ and 3.14 $rad \cdot s^{-1}$ during two visits. Intraclass correlation coefficients (ICCs), ICC confidence intervals (95% CI), coefficients of variation (CVs), and Pearson correlation coefficients were calculated.
Results: LE_{RTD} demonstrated no reliability. The CVs for LE_{RTD} and HG_{RFD} were ≤23.26%. HG_{MVC} wasn't related to leg extension torque or power, or balance ($r = 0.14$–0.47; $p > 0.05$). However, moderate to strong relationships were found among isokinetic leg extension torque at 1.05 $rad \cdot s^{-1}$ and 3.14 $rad \cdot s^{-1}$, leg extension mean power at 1.05 $rad \cdot s^{-1}$, and functional reach ($r = 0.51$–0.95; $p \leq 0.05$).
Conclusions: LE_{RTD} and HG_{RFD} weren't reliable and shouldn't be used as outcome variables in older men. Handgrip strength may not be an appropriate surrogate for lower body strength, power, or balance. Instead, perhaps handgrip strength should only be used to describe upper body strength or functionality, which may compliment isokinetic assessments of lower body strength, which were reliable and related to balance.

1. Introduction

Isometric and isokinetic assessments of handgrip and leg extensor muscle strength are commonly used to evaluate muscle function in older adults (Bento et al., 2010; Cannon et al., 2008; Den Ouden et al., 2011; Felicio et al., 2014; Thompson et al., 2013; Webber and Porter, 2010; White et al., 2013). It has been hypothesized recently that the rate of torque (RTD) or force (RFD) development measured during isometric muscle actions may be related to balance and risk of falls (Bento et al., 2010; Thompson et al., 2013). However, limited data exist regarding the reliability of these measurements (Cannon et al., 2008) or how they relate to functional measures of balance in older adults. Therefore, exploratory studies are needed in older adults to quantify the reliability of isometric torque, isokinetic torque, and RTD variables as well as explore relationships among these variables and functional outcomes such as balance.

The aims of this exploratory study were two-fold: (a) quantify the reliability of isometric leg extension peak torque (LE_{MVC}) and RTD (LE_{RTD}), isometric handgrip peak force (HG_{MVC}) and RFD (HG_{RFD}), isokinetic leg extension peak torque (PT) and mean power (MP) at 1.05 $rad \cdot s^{-1}$ and 3.14 $rad \cdot s^{-1}$, and functional reach, and (b) explore the relationships among muscle strength, power, and balance in older men.

2. Materials and methods

2.1. Subjects

Sixteen older men (mean ± standard deviation (SD) age = 72.1 ± 7.1 years; height = 178.4 ± 6.1 cm; mass = 81.0 ± 13.3 kg) volunteered for this study. Prior to testing, subjects signed an informed consent document and completed a health history questionnaire. Of the 16 subjects, 14 reported engaging in 1–11 $h \cdot wk^{-1}$ of aerobic exercise and 9 reported 1–4 $h \cdot wk^{-1}$ of resistance exercise. This study was approved by the University's Institutional Review Board for the Protection of Human Subjects (IRB Approval #20121213102FB).

2.2. Design

This was a repeated measures test–retest reliability study that required each subject to visit the laboratory on three occasions. Each laboratory visit was separated by 48–72 h and occurred at the same time of day (±2 h). During visit one, subjects were familiarized with the testing procedures. The familiarization visit allowed each subject to become

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accustomed to the laboratory equipment, the lab environment, and the testing procedures. During visits two and three, subjects completed the following tests: 3 maximal voluntary isometric handgrip muscle actions, 3 maximal voluntary isometric leg extension muscle actions, and 3 maximal voluntary isokinetic leg extension muscle actions at 1.05 $rad \cdot s^{-1}$ and at 3.14 $rad \cdot s^{-1}$.

2.3. Handgrip strength

Handgrip strength was measured with the dominant arm using a calibrated handgrip dynamometer (TSD121C, Biopac Systems, Santa Barbara, CA, USA). Subjects were positioned according to the recommendations of the American Society for Hand Therapy (Fess, 1992). Following 3 warm-up muscle actions, subjects completed three, 4 s maximal voluntary isometric handgrip muscle actions (MVCs). Subjects were instructed to squeeze "as hard and as fast as possible" and loud verbal encouragement was provided during each muscle action.

2.4. Leg extension strength

For all leg extension muscle actions, subjects were seated with straps securing their trunk, pelvis, and left thigh on a calibrated isokinetic dynamometer (Biodex System 3, Biodex Medical Systems, Inc., Shirley, NY, USA). The input axis of the dynamometer was aligned with the lateral epicondyle of the femur and the right leg was used for testing due to the experimental set-up, which limited testing to the right leg. The order of isokinetic and isometric testing was randomized at each visit. Four, submaximal warm-up leg extension muscle actions were completed at 25%, 50%, 75%, and 100% of the subject's perceived effort with 30 s of rest between each muscle action prior to each velocity (i.e., isometric, 1.05 $rad \cdot s^{-1}$, and 3.14 $rad \cdot s^{-1}$). A 2 min rest was then provided prior to the maximal leg extension strength testing. Subjects were instructed to extend "as hard and as fast as possible" and loud verbal encouragement was provided during each muscle action.

During the isometric muscle actions, the leg was flexed to 90° below the horizontal plane. Each subject completed three, 4 s MVCs of the leg extensors with 2 min of rest between attempts. The range of motion for the isokinetic leg extension muscle actions was set from 0° to 90°, with 0° representing full extension. Subjects completed three, maximal isokinetic muscle actions of the leg extensors at 1.05 $rad \cdot s^{-1}$ and 3.14 $rad \cdot s^{-1}$ with 1 min of rest allowed between repetitions. Two min of rest was allowed between each testing velocity and between isometric testing and isokinetic testing. The isometric or isokinetic repetition that yielded the greatest peak torque was selected for further analysis.

2.5. Functional reach

Each subject completed three functional reach assessments as described by Duncan et al. (1990). Briefly, subjects were asked to stand in a normal, relaxed stance perpendicular to a wall and a yardstick was secured to the wall at the height of the subject's acromion. The subjects then made a closed fist and extended their arm horizontally so that it was parallel to the floor. The placement of the end of the subjects' third metacarpal along the yardstick was recorded. Subjects then reached as far forward as they could without losing their balance or taking a step and the placement of the end of the third metacarpal along the yardstick was again recorded. The functional reach (cm) was calculated as the difference in the position of the third metacarpal before the reach and the position of the third metacarpal after the reach. Each subject completed three functional reach assessments, with the average of the greatest two used for subsequent analyses.

2.6. Signal processing

The torque, force, and velocity signals from the dynamometers were sampled at 2 kHz (MP150WSW, Biopac Systems, Inc., Santa Barbara, CA, USA), recorded on a personal computer, and processed off-line with custom software (Labview 12.0, National Instruments, Austin, TX, USA). The torque and force signals were low-pass filtered (15 Hz cutoff, zero-phase shift Butterworth filter).

LE_{MVC} (Nm) and HG_{MVC} (kg) were calculated as the highest 500 ms average torque or force obtained during the plateau of each MVC. LE_{RTD} and HG_{RTD} were calculated as the mean of the first derivative of the torque ($Nm \cdot s^{-1}$) or force ($kg \cdot s^{-1}$) signal occurring between 20% and 80% of the onset and peak of the torque or force signals (Cannon et al., 2008). PT 1.05 $rad \cdot s^{-1}$ and PT 3.14 $rad \cdot s^{-1}$ were calculated as the highest 25 ms average torques that occurred during the isokinetic load range. The load range has been defined (Brown and Whitehurst, 2000) as the portion of the available range of motion where there is a ". match between isokinetic velocity and limb movement" (p. 97). The MP 1.05 $rad \cdot s^{-1}$ and MP 3.14 $rad \cdot s^{-1}$ (W) were calculated as the product of the average torque (Nm) during load range and isokinetic velocity ($rad \cdot s^{-1}$).

2.7. Statistics

2.7.1. Reliability

One-way repeated measures analyses of variance (ANOVAs) were used to compare the means between visits 2 and 3 for systematic variability. Test–retest reliability was calculated by determining the intraclass correlation coefficient (ICC; relative reliability) using Model "2,k" (Brown and Whitehurst, 2000). In addition, the 95% confidence interval (95% CI) for each $ICC_{2,k}$ was calculated according to the procedure described previously (Shrout and Fleiss, 1979). The 95% CI was used to test the null hypotheses that each ICC was equal to zero (Vincent and Weir, 2014).

For measures of absolute reliability, the standard error of the measurement (SEM) was calculated across visits two and three using the following equation (Hopkins, 2000; Weir, 2005):

$$SEM = \sqrt{MS_E}. \quad (1)$$

The coefficient of variation (CV) was calculated as a normalized measure of the SEM using the following equation (Hopkins, 2000):

$$CV = \frac{SEM}{Grand\ \ mean} \times 100. \quad (2)$$

2.7.2. Relationships

Pearson product moment correlation coefficients were calculated to examine the relationships among the dependent variables during visit three. A type I error rate of 5% was considered statistically significant for all analyses.

3. Results

3.1. Reliability

The grand means, standard deviations, and reliability statistics for each dependent variable are displayed in Table 1. There was no systematic variability for any of the dependent variables ($p > 0.05$). The ICC for LE_{RTD} was not different from zero (95% CI $= -0.05$–0.76). All other ICCs were greater than zero ($p \leq 0.05$). The CVs for LE_{RTD} and HG_{RTD} were 23.26% and 42.80%, respectively; whereas the CVs for LE_{MVC}, HG_{MVC}, PT 1.05 $rad \cdot s^{-1}$, MP 1.05 $rad \cdot s^{-1}$, PT 3.14 $rad \cdot s^{-1}$, MP 3.14 $rad \cdot s^{-1}$, and functional reach were all $\leq$16.10%.