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Test–retest reliability of sensor-based sit-to-stand measures in young and older adults

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ABSTRACT

This study investigated test–retest reliability of sensor-based sit-to-stand (STS) peak power and other STS measures in young and older adults. In addition, test–retest reliability of the sensor method was compared to test–retest reliability of the Timed Up and Go Test (TUGT) and Five-Times-Sit-to-Stand Test (FTSST) in older adults. Ten healthy young female adults (20–23 years) and 31 older adults (21 females; 73–94 years) participated in two assessment sessions separated by 3–8 days. Vertical peak power was assessed during three (young adults) and five (older adults) normal and fast STS trials with a hybrid motion sensor worn on the hip. Older adults also performed the FTSST and TUGT. The average sensor-based STS peak power of the normal STS trials and the average sensor-based STS peak power of the fast STS trials showed excellent test–retest reliability in young adults (intra-class correlation (ICC) $\geq$ 0.90; zero in 95% confidence interval of mean difference between test and retest (95%CI of *D*); standard error of measurement (SEM) $\leq$ 6.7% of mean peak power) and older adults (ICC $\geq$ 0.91; zero in 95%CI of *D*; SEM $\leq$ 9.9%). Test–retest reliability of sensor-based STS peak power and TUGT (ICC = 0.98; zero in 95%CI of *D*; SEM = 8.5%) was comparable in older adults, test–retest reliability of the FTSST was lower (ICC = 0.73; zero outside 95%CI of *D*; SEM = 14.4%). Sensor-based STS peak power demonstrated excellent test–retest reliability and may therefore be useful for clinical assessment of functional status and fall risk.

1. Introduction

Functional status and fall risk are often evaluated with simple field tests in older adults, such as the Timed Up and Go Test (TUGT) and Five-Times-Sit-to-Stand Test (FTSST) [1–4]. However, these field tests provide a crude outcome measure (time in seconds) with limited clinical relevance. For example, TUGT and FTSST scores do not provide a highly accurate prediction of future falls [5,6]. Therefore, methods that assess additional aspects of movement performance may contribute to the evaluation of functional status and fall risk in older people.

Studies show that leg strength and leg power decline during aging [7,8], and that reduced strength and power of leg muscles is related to a lower mobility performance and an increased fall risk [8–10]. Therefore, assessment of leg strength and leg power may contribute to the evaluation of functional status and fall risk. The use of body-fixed motion sensors during sit-to-stand (STS) movements may provide clinicians with a practical method to estimate power of leg muscles, since a recent study showed that

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vertical peak power during the STS transfer can be estimated based on the vertical acceleration signal of hybrid motion sensors worn on the trunk in young and older adults [11].

However, test–retest reliability of STS peak power estimated with hybrid motion sensors is unknown. Therefore, this study investigated test–retest reliability of sensor-based STS peak power and related measures in young and older adults. Young adults were included to investigate whether reliability of sensor-based STS measures is consistent among young and older adults. Assuming consistent reliability in young and older adults, the reliability results in young adults were used to estimate the sample size needed for the older adult reliability study. This study also investigated the smallest number of STS trials necessary for excellent test–retest reliability of sensor-based STS measures. To determine whether the sensor-based STS measures can be of added value to clinicians, this study also compared the test–retest reliability of the sensor-based STS measures to the test–retest reliability of standard clinical measures of functional status (TUGT and FTSST) in older adults. Based on the excellent test–retest reliability of sensor-based STS peak power in young adults, we hypothesized that the test–retest reliability of sensor-based STS peak power would be excellent in older adults and comparable to the test–retest reliability of the TUGT and FTSST in older people.

2. Methods

2.1. Participants

Ten healthy young female adults were recruited among students from the University of Groningen. They voluntarily decided to participate in this study. Age ranged from 20 to 23 years (mean ± SD: 21.9 ± 1.2 years), height ranged from 1.65 to 1.84 m (1.73 ± 0.06 m) and body mass ranged from 55.5 to 77.0 kg (66.0 ± 7.4 kg). All females were free of health issues that might influence STS performance.

The required number of older adults was calculated using a statistical model [12]. An intra-class correlation (ICC) of 0.75 was defined as the minimally acceptable ICC, since ICC ≥ 0.75 is considered to indicate excellent reliability [13]. The smallest ICC (ICC = 0.90) of our most important outcome measure (sensor-based STS peak power) in young adults was chosen as the expected ICC. With two assessments (test and retest) per subject, the statistical model indicated that at least 27 subjects were needed to establish that the expected ICC (0.90) was significantly different from the minimally acceptable ICC (0.75) with a significance level of 0.05 and a power of 0.80.

Older adults were recruited in a residential care home, sheltered houses and a health care center. Inclusion criteria were: ≥70 years of age, being able to walk ≥10 m (the use of a wheeled walker or cane was allowed), and being able to stand up from a chair. Exclusion criteria were: cardiovascular/respiratory disorders, neurological disorders, severe comorbidity, cognitive disorders that affect comprehension or execution of the physical tests, simultaneous participation in an intervention or exercise program, orthopedic surgery in the previous six months, visual problems to a degree that makes it impossible to walk or stand up safely from a chair, a stroke within the last six months.

In total 31 healthy older adults (21 females, 10 males) voluntarily decided to participate. Age ranged from 73 to 94 years (mean ± SD: 82.5 ± 4.9 years), height ranged from 1.46 to 1.89 m (1.66 ± 0.10 m) and body mass ranged from 48.0 to 104.4 kg (79.9 ± 14.3 kg). Thirteen older adults reported they had fallen at least once in the year before this study. A fall was defined as 'unintentionally coming to rest on the ground, floor or other lower level' [14]. Self-reported number of falls in the last year ranged from 0 to 4.

All participants signed an informed consent before participating in the study. The study was approved by the Medical Ethical Committee of the University Medical Center Groningen, Groningen, The Netherlands.

2.2. Measurements

Subjects participated in two assessment sessions (test and retest), separated by five to seven days (young adults) and three to eight days (older adults). During both assessment sessions, young adults and older adults performed STS movements. Older adults also performed the FTSST and the TUGT during both assessment sessions.

2.2.1. STS movements

2.2.1.1. Test procedure. Young adults performed three normal as well as three fast STS transfers and older adults performed five normal STS transfers. When older adults had no difficulty with standing up from a chair, they were also requested to perform five fast STS transfers. Before rising from the chair, participants were instructed to sit against the back of the chair. Participants were asked to perform the STS transfers with their arms crossed in front of the chest. After rising from the chair, participants stood still for 5 s before sitting down again. After sitting down, participants were sitting still for 10 s before standing up again. A chair with arm rests and a standard height of 0.47 m was used.

2.2.1.2. Data acquisition. During the normal and fast STS movements participants wore a hybrid motion sensor (π-Node, Philips) on the right side of the hip (a small distance above the trochanter major femoris). The hybrid motion sensor consisted of a 3D accelerometer (±2 g), a 3D gyroscope (±300°/s) and a 3D magnetometer (±2 Gauss) [15]. Data were sampled with 50 Hz and wirelessly transmitted to a PC by using a proprietary multipoint packetized radio protocol [16].

2.2.1.3. Data analysis. Matlab (The Mathworks, Inc.; version 7.12) was used for data analysis. The sensor orientations and accelerations in the global coordinate system were calculated by using quaternions and the data of the accelerometer, gyroscope and magnetometer in the sensor coordinate system [15]. Subsequently, the acceleration data in the global coordinate system were filtered with a low-pass Butterworth filter using 3 Hz as cut-off frequency.

The low-pass filtered vertical acceleration data were used to calculate the following STS measures:

1. **STS duration:** Time between the initiation of the forward trunk rotation before rising (identifiable as the first deflection of the acceleration compared to gravity) and the first intersection of the acceleration signal with the acceleration due to gravity, after the deceleration phase (for further explanation see Fig. 3 in [17]).
2. **Maximal acceleration:** The maximal acceleration during the interval of STS duration.
3. **Maximal jerk:** The highest positive jerk during the acceleration phase of the rising movement. Jerk was computed as: $\text{Jerk}_i = (a_{i+1} - a_i)/(1/f_s)$. The a represents acceleration, i the sample and f_s the sample frequency.
4. **Maximal velocity:** The maximal velocity during the interval of STS duration. Velocity was estimated by numerical integration of acceleration. The assumption was used that velocity was 0 m/s at the start of the STS duration interval.
5. **Peak power:** The peak power during the STS duration interval. Power was calculated for every sample in the STS duration interval [11]. Force and velocity were multiplied to estimate