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Validity and reliability of an iPhone App to assess time, velocity and leg power during a sit-to-stand functional performance test

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ABSTRACT

The purposes of this study were: (i) Analyze the concurrent validity and reliability of an iPhone App for measuring time, velocity and power during a single sit-to-stand (STS) test compared with measurements recorded from a force plate; and (ii) Evaluate the relationship between the iPhone App measures with age and functional performance. Forty-eight healthy individuals (age range: 26–81 years) were recruited. All participants completed a STS test on a force plate with the movement recorded on an iPhone 6 at 240 frames-per-second. Functional ability was also measured using isometric handgrip strength and self-paced walking time tests. Intraclass correlation coefficients (ICC), Pearson's correlation coefficient, Cronbach's alpha (α) and Bland-Altman plots with 95% confidence intervals (CI) were used to test validity and reliability between instruments. The results showed a good agreement between all STS measurement variables; time (ICC = 0.864, 95%CI = 0.77–0.92; α = 0.926), velocity (ICC = 0.912, 95%CI = 0.85–0.95; α = 0.953) and power (ICC = 0.846, 95%CI = 0.74–0.91; α = 0.917) with no systematic bias between instruments for any variable analyzed. STS time, velocity and power derived from the iPhone App show moderate to strong associations with age (|r| = 0.63–0.83) and handgrip strength (|r| = 0.4–0.64) but not the walking test. The results of this study identify that this iPhone App is reliable for measuring STS and the derived values of time, velocity and power shows strong associations with age and handgrip strength.

1. Introduction

The sit-to-stand (STS) test is a reliable tool to measure functional mobility [1], which declines considerably with increased age [2], disease and disability [3] and has been considered a physical marker of ageing along with handgrip strength or walking speed [4,5]. Sit-to-stand time increases with age, likely the consequence of slower leg velocity and reduced muscle power [6,7]. Leg velocity and power are often correlated with changes in handgrip strength and walking speed, both influence age-related decline in functional mobility [8,9]. Therefore, changes in STS performance may be considered as an important measure of physical independence.

Although time to complete the STS is the primary measure of function, leg velocity and muscle power also contribute to understanding physical performance [10]. However, measurement of velocity and power require more sophisticated assessment tools such as a force plate [11,12], accelerometer [13,14], force transducers [7] and/or motion capture systems [15]. This technology, although sensitive to small changes in STS performance is not readily available or affordable for clinical or field-based testing environments and some current methods remain complex, difficult and time consuming to analyze [5]. Recent advances in hand-held technology offer an opportunity to assess leg velocity and power through a smartphone mobile application (App). Recently App technology was used to justify the validity and reliability of the Timed-Up and Go [14,16] and the five-time STS [16] assessment protocols. However, these Apps do not provide analysis of leg velocity or power [14,16]. Leg power is a product of the force (Newtons; N) × the velocity (meters/second; m/s) generated during the movement, and is considered a good measure of fall risk [13] and age-related functional decline [7]. To our knowledge, there is no App technology currently available to objectively measure time, velocity and power during a single STS test captured from a video recording using a smartphone device.

The primary objective of this study was to determine the concurrent validity and reliability of an iPhone App for measuring time, velocity and power during a single-STS test compared with established

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measurements recorded from a force plate. The secondary objective was to ascertain whether these measurement variables were related to age, handgrip strength, and self-selected walking speed.

2. Methods

The App (*Sit-to-stand App version 1.0.8*) was developed using Xcode 8.3.2 and the Swift 3.1 programming language (*Apple Inc., USA*) for Mac OS X (*Apple Inc., USA*). For capturing, importing and manipulating high-speed videos the AVFoundation and AVKit frameworks (*Apple Inc., USA*) were used. The App was designed for analyzing STS test via high-speed video recording (240 frames-per-second) to allow the calculation of time between two frames selected by the user and subsequent calculation of the mean vertical velocity and mean vertical power relative to body weight. After the calculation of the time during STS test, the App used the following Newtonian equation for calculating mean vertical velocity:

$$V = d/t \quad (1)$$

where the mean vertical velocity is equal to the femur length (*d*), the distance between the superior aspect of the greater trochanter and lateral condyle of the femur, divided by the time in seconds (s) to rise from the chair *(t)*, as measured between two user selected frames. Subsequently, mean vertical power (*Pmean)* was estimated from the following equation:

$$Pmean = 2.773–6.228 \times t + 18.224 \times d \quad (2)$$

Pmean was integrated into the App software. This regression equation was developed using data previously acquired from a force plate (*AMTI SGA 6-3, MA, USA*) in a sample of 17 healthy subjects (10 males; Range: age = 26–81 years, body weight = 53.5–98.7 kg, femur length = 0.33-0.45m, time of rising phase = 0.30–1.11 s, *Pmean* = 3.26–8.86 W/kg). The *Pmean* and time *(t)* of the rising phase from the force plate and the femur length *(d)* were used to develop the multivariate regression analysis (r^2 *adjusted = 0.917; p = 0.035; standard error of estimate(SEE) = 0.45)* using SPSS Statistics 19.0 (*IBM SPSS Inc. USA, 2010*).

2.1. Participants

Forty-eight healthy individuals (25 women), (mean and [range]: age = 50.6 [21–87] years, height = 1.68 [1.5–1.85]m, body weight = 71.9 [50.2–125.5]kg, femur length = 0.389 [0.33–0.39]m, time to rising = 0.53 [0.35–0.80] sec) were recruited for the validation study. Eight males were removed for Objective 2 due to missing data from the functional test battery (handgrip and walking tests). Thus, 40 healthy individuals were used to assess the relationship between the App measurement variables with age, handgrip strength and self-selected walking speed (Table 1). All procedures conformed to the Declaration of Helsinki and this study was approved by the Behavior Research Ethics Board at the University of British Columbia and at the Catholic University of Murcia. Written informed consent was obtained from each participant in advance.

2.2. Objective 1–validity and reliability

Prior to the execution of STS test, the superior aspect of greater trochanter and lateral condyle of the femur on the right side of the participant were marked with colored stickers to measure the femur length. Femur length measured with an anthropometric measuring tape by JDR or JJR. Participants completed three STS repetitions to complete the test while standing without footwear on a force plate (*AMTI SGA 6-3, MA, USA*). Each STS repetition was recorded on video using the iPhone App (*Sit-to-stand App version 1.0.8*) installed on an iPhone 6 running iOS 10.2.1 (*Apple Inc., USA*). Each repetition was recorded at 240 frames-per-second at a quality of 720 pixels. The iPhone was not attached to the participant, rather it was positioned on a 0.7m-high tripod placed 3 m from the force plate on the right side of the participant (Fig. 1).

Table 1
Sample characteristics (n = 40).

	Mean	SD	Minimum	Maximum
Age (years)	53.1	23.83	21	87
Weight (kg)	69.6	13.31	50.2	113.4
Height (m)	1.66	0.085	1.50	1.85
Femur length (m)	0.38	0.039	0.33	0.49
Walking time (s)	2.81	0.52	1.98	5.04
Handgrip (kg)	66	19.94	26.8	112.3
STS App variables				
STS time average (sec)	0.50	0.09	0.375	0.7
STS time fastest (sec)	0.47	0.09	0.346	0.7
Mean vertical velocity average (m/s)	0.79	0.16	0.48	1.18
Mean vertical velocity fastest (m/s)	0.85	0.17	0.49	1.22
Pmean average (W/kg)	6.69	0.91	4.62	8.60
Pmean fastest (W/kg)	6.89	0.90	4.66	8.68

Data are given as mean, standard deviation (SD) and range. Sit-to-stand (STS). Mean power relative to body weight (*Pmean*). Average of three repetitions (average). Fastest repetition (fastest). Kilograms (kg), meters (m), seconds (sec), meters per second (m/s), Watts per kilogram (W/kg).

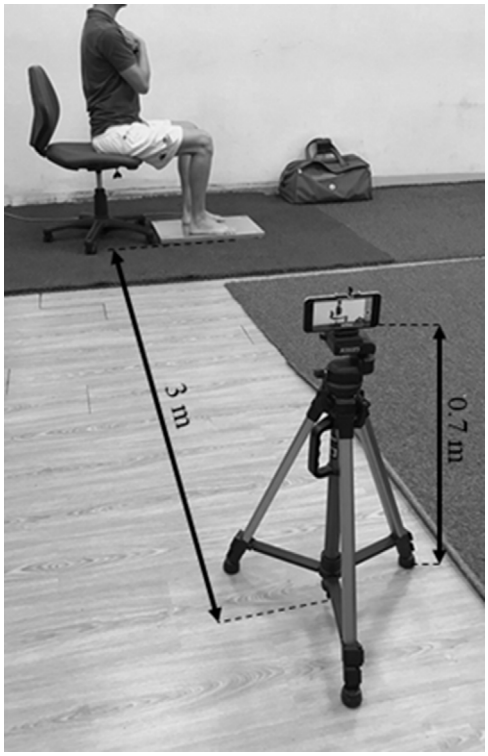

Fig. 1. Measurement environment. iPhone positioned on a 0.7 m-high tripod placed 3 m from the right side of the participant.

To execute the test, subjects sat on a rigid chair with their arms crossed over their chest with the hip, knee and ankle joints at approximately 90° as previously reported [13,17]. Both feet rested on the force plate and the subjects were instructed to stand-up as fast as possible.

2.3. Data analysis

Video analysis from the STS App was undertaken by two independent, blinded observers (JDR, JJR). To objectively determine the onset and end position of the final movement, a visual grid (3.8 × 3.8