Concurrent and discriminant validity and reliability of an Android App to assess time, velocity and power during sit-to-stand test in community-dwelling older adults

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Abstract

Introduction Nowadays, smartphones are equipped with the most sophisticated hardware which provides the opportunity to develop specific smartphone apps to analyze kinetic and kinematic parameters during sit-to-stand test in a clinical setting. The aims were to ascertain whether a new Android video-analysis based-App is comparable to the previously validated Apple-App for measuring time, velocity and power during sit-to-stand test, to determine its reliability and discriminant validity.

Methods One-hundred sixty-one older adults (61–86 years) were recruited from an elderly social center. Sit-to-stand variables were simultaneously recorded through the Android and Apple-App. Their validity and inter-rater, intra-rater, and test–retest reliability was tested using an intraclass correlation coefficient ($ICC_{2\text{-}1}$). Low gait speed (< 1.0 m/s), low physical performance (Short Physical Performance Battery < 10 points), and sarcopenia (EWGSOP2 guideline) were used to determine discriminant validity which was reported as the area under the curves (AUC) and their effect sizes (Hedges' *g*) for independent sample *t*-test.

Results Excellent reproducibility ($ICC_{2\text{-}1} > 0.85$) and strong agreement ($ICC_{2\text{-}1} > 0.90$) between operating systems for sit-to-stand variables derived from the App was found. Older adults classified as sarcopenic (11.2%), low physical performance (15.5%), or reduced gait speed (14.3%) showed worse sit-to-stand time, velocity and power with large effect sizes (Hedges' *g*: > 0.8) compared to their respective counterpart. These variables showed the acceptable-to-excellent ability to identify low gait speed, low physical performance, and sarcopenic older adults (AUC-range: 0.73–0.82).

Conclusion The new *Sit-to-Stand* App running on the Android operating system is comparable to the previously validated Apple App. Excellent reproducibility and acceptable-to-excellent discriminant validity were found.

Keywords Validity · Reliability · Agreement · Sit-to-stand · Smartphone · Older adults

Introduction

Ageing is associated with a progressive decline across multiple physiological systems which limit the ability to develop activities of daily living such as rising from a chair. Inability to rise from a chair without using the arms of the chair is considered a biomarker of aging [1, 2] and has been independently associated up to four times increase risk of mortality in community-dwelling older adults [2]. Kinetic and kinematic analyses during rising from a chair have been widely investigated for years with the aim of detecting age-related functional impairments [3–5] and for developing strategies that minimize functional deficits in older adults [6–8]. Variables derived from kinetic and kinematic analyses during sit-to-stand test have been related to the ageing process [9] and health-related outcomes such as falls [4], poor physical

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function [10, 11], sarcopenia [12] or even frailty [13, 14]. Early detection and treatment of these deficits could prevent subsequential age-related functional decline. However, these analyses have been usually restricted to research setting mainly due to the limitations imposed by specific tools which are very expensive, require technical expertise, are not portable and are time-consuming to analyze. These issues represent barriers for clinicians that require low-cost easy-to-use tools with automatic data processing and without the need for complex instrumentation or specialized personnel.

Nowadays, in a world powered by technology, smartphones are equipped with the most sophisticated hardware similar to those found in a laboratory setting, such as inertial measurement units or high-speed video cameras which provide the opportunity to develop specific smartphone apps to analyze kinetic and kinematic parameters in the clinical setting [9, 15, 16]. In an attempt to overcome the aforementioned barriers, our research group developed and validated a consumer Apple App to analyze the rising phase of the sit-to-stand movement via high-speed video recording through an easy-to-use interface and an automatic data processing after video analysis which allows clinicians to obtain kinetic and kinematic parameters such as the time to rising, vertical velocity and vertical power during the sit-to-stand functional performance test in short-time periods [9]. Our App showed negligible bias and small errors compared to force plate [9] and 3D motion capture camera [15] in adults with a broad age range (21–91 years). Moreover, these variables have been related to several measures of physical function [9, 10, 13–15] and enhance the information obtained from functional tests currently used in clinical practice [13, 17, 18].

However, the main weakness of this App is the compatibility restriction to Apple devices which affects the accessibility to clinicians with Android operating system (OS) smartphones. Therefore, to make this tool available to the two most widely used mobile OS, we developed a new *Sit to Stand* App compatible with Android OS. Yet, prior to recommend its use it is mandatory to develop a validation process to ascertain whether the new Android App is equivalent to the previously validated Apple one [9, 15] since changing the mobile OS could lead to different measurement errors affecting their data accuracy and validity [19]. In fact, a recent study aimed to validate four famous step count based-Apps reported considerable differences in terms of accuracy between the same Apps running simultaneously on different OS [19]. Therefore, a previously validated App designed for Apple iOS might not be valid for Android OS (or vice versa) and a validation process is required prior to recommend its use.

The aims of this study were (1) to ascertain whether the new Android App is comparable to the previously validated Apple App, (2) to determine the intra-rater, inter-rater, and test–retest reliability, and (3) to analyze the discriminant validity of this App to differentiate community-dwelling older adults with sarcopenia, low gait speed and low physical performance with their respective counterpart.

Materials and methods

Study design

This was a cross-sectional study design aimed to assess the validity and reliability of the new *Sit to Stand* App installed on a Samsung A52 G device (Samsung Electronics Co., Ltd., Suwon, South Korea) running Android OS 14.0. The study was designed according to the Guidelines for Reporting Reliability and Agreement Studies (GRRAS) [20] (see Supplementary Information). The study was developed in an elderly social center in the city of Murcia (Spain) from February to October 2022. All data collection was collected on the same day. Primary outcomes were rising time, vertical velocity, and vertical power derived from the *Sit to Stand* App which were used for agreement and reliability analysis. Secondary outcomes were sarcopenia, gait speed, and physical performance assessed with the Short Physical Performance Battery which were used for discriminant validity. This study was developed in parallel with the previously published protocol [21] NCT05148351 at ClinicalTrials.gov.

Eligibility criteria

A non-probability sample of community-dwelling adults aged 60 or more was enrolled from an elderly social center in the city of Murcia. Participants were contacted either face-to-face or via telephone to participate in the study. Exclusion criteria were participants at risk of dementia (Mini-Cog $<$ 3 points), self-reporting cardiovascular problems (automatic defibrillator, pacemakers, heart valve disease, and uncontrolled heart rhythm problems), unable to stand up from a chair without assistance, or any health condition that affects the performance of the functional tests such as stroke sequelae, low back pain or osteoarthritis. Physical activity level was measured with the Spanish Short Version of the Minnesota Leisure Time Physical Activity Questionnaire. Participants were informed of the study procedures before providing written informed consent and the study was approved by the Ethical Committee of the Catholic University of Murcia (CE022108). All procedures conformed to the Declaration of Helsinki.

Procedures

The *Sit to Stand* App (version 1.0) was developed using Android Studio Chipmunk 2021.2.1 Patch 1, the Kotlin 1.5.21 programming language and the Compose 1.0.1 UI framework for MacOS. For capturing, importing and manipulating high-speed videos the CameraX 1.1.0 framework was used. The App was designed to analyze the rising phase of the sit-to-stand movement via high-speed video recording at 240 frames-per-second. The variables provided by the App are rising time, vertical velocity, and vertical power. Vertical velocity is calculated from vertical displacement (*d*) which is introduced into the App by the user and automatically divided by the rising time (*t*), as obtained between two user-selected frames after analyzing the video. Vertical displacement is equal to the femur length, the distance between the superior aspect of the greater trochanter and femoral lateral condyle when the participant sat at 90 degrees of the knee joint. Subsequently, vertical power is estimated from the following regression equation (R^2 adjusted = 0.917; $p = 0.035$; *standard error of estimate* = 0.45) [9, 15]:

$$\text{Power (W/Kg)} = 2.773 - 6.228 \times t + 18.224 \times d$$

After obtaining written informed consent, participants performed the single sit-to-stand test, sarcopenia assessment, gait speed test, and the Short Physical Performance Battery at the same day.

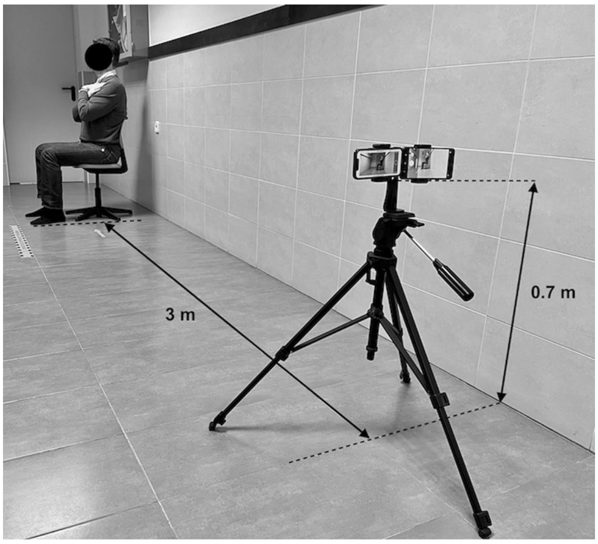


Fig. 1 Measurement environment. *Sit to Stand* App running on Apple and Android OS positioned on a 0.7 m-high tripod using a dual mount adapter placed 3 m from the left side of the participant

Single sit-to-stand test

Prior to the execution of the test, the distance between the superior aspect of the greater trochanter and the femoral lateral condyle of the participants was measured using an inelastic but flexible measuring tape. A visual marker (colored sticker) was placed on the greater trochanter to identify the beginning and the end of the rising phase. The sit-to-stand movement was simultaneously recorded with two smartphone models running the *Sit to Stand* App, the Samsung A52 G device running Android OS 14.0 and the iPhone 13 device running iOS 15.3. The smartphones were placed horizontally on a 0.7 m-high tripod placed 3 m from the left of the participant using a dual mount adapter (Fig. 1). Participants were instructed to stand up "as fast as possible" from an adjustable height chair without footwear with their arms crossed over their chest and the hip, knee, and ankle joints at 90 degrees. Three repetitions were performed and the fast repetition was used for further analyses. After 30 min of rest, participants were instructed to repeat the sit-to-stand test for test–retest reliability purposes.

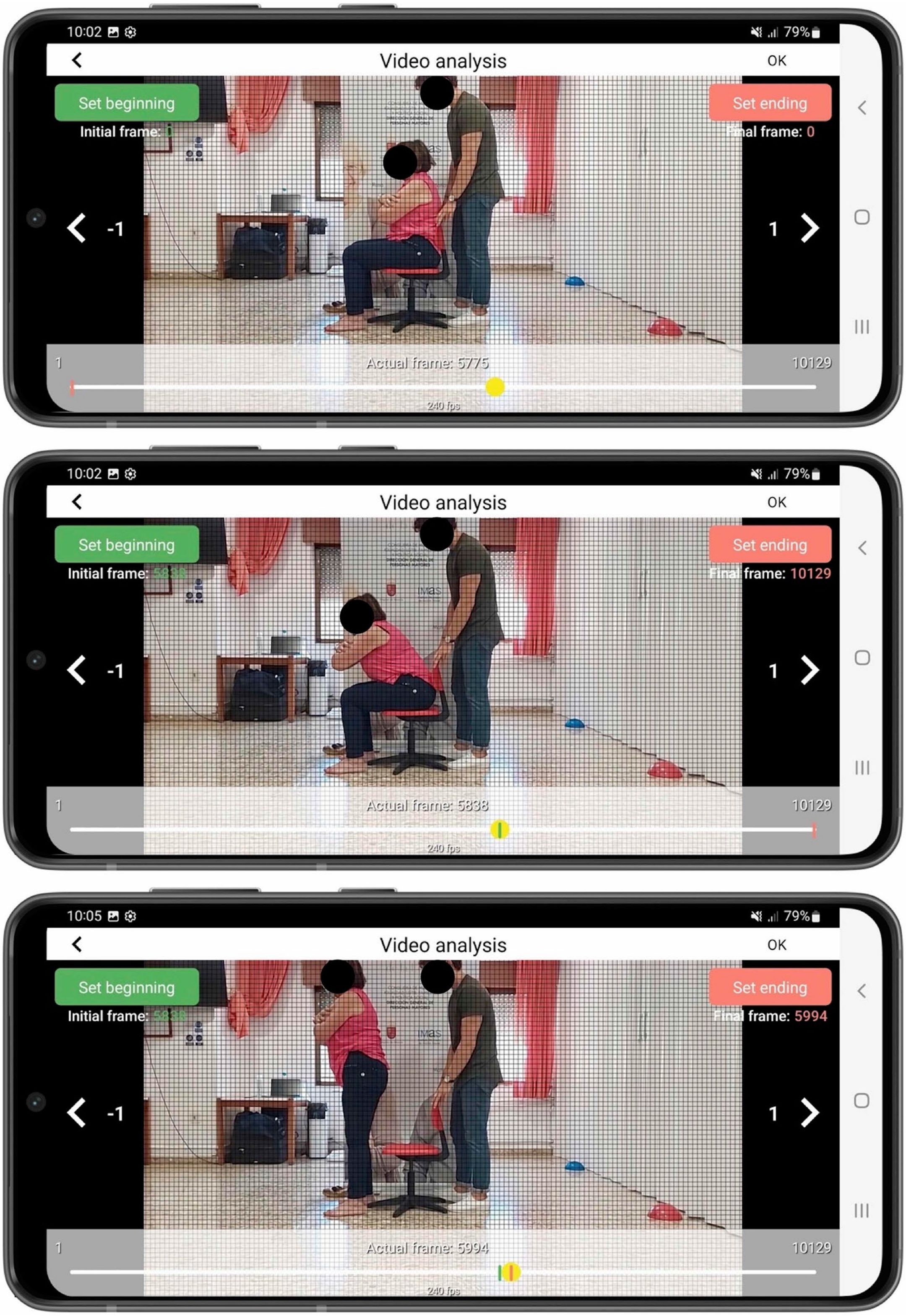
Rater characteristics and data analysis

Video analysis from both Apple and Android Apps was undertaken by two independent raters for inter-rater analysis. For intra-rater analysis, one rater analyzed twice the videos from the Android App one-week apart. The raters were blinded to each other's findings in the case of inter-rater analysis, to their own analysis one week apart in the case of intra-rater analysis, and to participant characteristics, *i.e.,* sarcopenia, gait speed and physical performance measures, in the case of discriminant analysis.

To objectively determine the onset and the end of the rising phase, a visual grid for reference was built into the App as an overlay (Fig. 2). According to the instruction of the App, the onset of the rising phase was determined when the pelvis began to move forward after anterior trunk tilt which is time-matched when the colored sticker crossed the first horizontal grid line on the screen of the App. The end of this phase was defined when full extension of hip and knee is achieved in an upright stance which is time-matched when the colored sticker achieves the highest vertical point.

Sarcopenia assessment

The presence of sarcopenia was determined following the recommendations provided by the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) [22]. Subjects were instructed to complete, as rapidly as possible, five chairs stand repetitions on a 0.45 m chair with their arms crossed over the chest. A stop-watch was started with the word "Go" and stopped when the participant sat on the chair for the fifth time [23]. Probable sarcopenia was defined with a cut-off point of > 15 s during the chair stand test. Then, sarcopenia was confirmed when the participant shows reduced appendicular skeletal muscle mass (cut-off point lower than 20 and 15 kg for men and women, respectively). Muscle mass was estimated using bioelectrical impedance analysis (TANITA MC-580, Tanita Corp., Tokyo, Japan). Resistance


10:02
79%
Video analysis
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Initial frame:
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OK
Set beginning
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Final frame: 5994
-1
1
1
Actual frame: 5994
10129
240 fps

◂**Fig. 2** User interface of the *Sit to Stand* App running on Android OS. White dot represents the colored sticker placed on the greater trochanter while the subject was at rest (top panel), at the beginning of the vertical movement (end of the preparation phase) when white dot crossed the first horizontal grip line on the screen (middle panel), and at the end of the rising phase when white dot achieved the highest point (lower panel). Example of a subject with 0.37 m of femur length. Rising time: 0.65 s; Velocity: 0.569 m/s; Power: 5.47 W/Kg

index and reactance raw values were used in the validated equation developed by Sergi et al. [24] as recommended by the EWGSOP2 [22].

Low gait speed

Low gait speed was defined with a cut-off < 1.0 m/s since it has been associated with an increased risk of hospitalization and mortality in well-functioning older adults [25]. Gait speed was measured via stop-watch using 4-m walking test. Two meters were provided prior to and following the timed portion (4-m) to allow for acceleration and deceleration phases. Participants were instructed to walk at their normal comfortable pace. The test was completed two times to improve the accuracy of the procedure and the fastest was selected for further analysis.

Low physical performance: short physical performance battery

Low physical performance was assessed through the Short Physical Performance Battery and defined with a cut-off < 10 points since it has been shown to be predictive of all-cause of mortality [26]. This battery includes the measure of gait speed, balance, and five repetitions chair stand test. Gait speed was measured as previously described. Balance was evaluated by examining the ability to stand with the feet together in the side-by-side, semi-tandem, and tandem position for 10 s. The five-times chair rising test was performed in a fixed-height chair (0.45 m) as previously described. A stop-watch was started on the word "Go" and unlike to sarcopenia assessment the stop-watch was stopped when the participant achieved the standing position at the end of the fifth stand [27].

Statistical analysis

Objective 1 and 2—reliability and concurrent validity

To determine the reliability and concurrent validity of sit-to-stand variables (time, velocity, and power) between the *Sit to Stand* App running Android OS compared to those obtained from the Apple iOS, Pearson's correlation coefficient (r) with 95% confidence intervals (CI), intra-class correlation coefficient two-way mixed effects absolute agreement (ICC_{2-1}) with 95% CI and Cronbach's alpha were used. Mean absolute percentage error (MAPE) and coefficient of variation were also calculated. To identify potential systematic bias Bland–Altman plots were conducted. Furthermore, to test the inter- and intra-rater reliability of the sit-to-stand variables from the Android App as well as to identify potential systematic differences, the ICC_{2-1} absolute agreement with 95% CI was used. Finally, to determine test–retest reliability two measures from the same subjects 30 min apart were selected and the ICC_{2-1} absolute agreement with 95% CI was used. Reliability was interpreted as poor (< 0.5), moderate (0.5 to < 0.75), good (0.75 to 0.9), and excellent (> 0.90). The minimal detectable change (MDC_{95}) which is the minimal amount of change in the score of an instrument that must occur in an individual to be sure that the change in score is not simply attributable to a measurement error was calculated for test–retest reliability and expressed as absolute and percentage of change.

Objective 3—discriminant validity

Independent sample t test was used to compare means of sit-to-stand variables between subjects classified as low usual gait speed, low physical performance, and sarcopenic and their respective counterpart. The effect sizes were calculated as Hedges' g, which was interpreted as small (< 0.2), medium (0.2 to 0.8), or large (> 0.8) effect and the Common Language Effect Size (CLES) was calculated to estimate the probability of a random observation from one population being larger than a random observation from the other population. Additionally, the Area Under the Curve (AUC) of the receiver operating characteristic was calculated to evaluate the discriminatory capacity of the sit-to-stand variables to differentiate subjects classified as low usual gait speed, low physical performance, and sarcopenic. AUC scores were interpreted as poor (0.5 to < 0.7), acceptable (0.7 to < 0.8), excellent (0.8 to < 0.9), and (≥ 0.9) outstanding discrimination. Given a sample size of 161 participants, the study was sufficiently powered (> 80%) to detect an effect size that was 0.8 (Hedges' g) or larger for two-tailed test.

Results

Participant and rater characteristics

A total of 174 community-dwelling older adults from an elderly social center were initially recruited. Six older adults were classified at risk of dementia (Mini-Cog < 3 points), four individuals were unable to stand up from a chair without assistance, and three data were lost due to unintentional video deletion. Therefore, a total of 161 community-dwelling older adults were finally recruited (Table 1) from which 322

Table 1 Sample characteristics ($n = 161$)

	Mean	SD	Minimum	Maximum
Age (years)	72.05	5.3	61	86
Weight (Kg)	69.91	12.4	45	104.8
Height (m)	1.59	0.08	1.38	1.79
Femur Length (m)	0.37	0.03	0.27	0.435
ASMM (Kg)	17.06	6.99	9.59	84.95
Physical Activity Level[a] (MET-min·week^{-1})	2355.7	–	1669.1	3402.3
Usual Gait Speed (m/s)	1.23	0.26	0.49	2.42
SPPB (pts)	11.41	0.98	5.00	12.00
Five Chair Rising Test (s)	12.04	2.60	7.42	25.88
Low Physical Performance (*n*. %)	25 (15.5%)	–	–	–
Low Usual Gait Speed (*n*. %)	23 (14.3%)	–	–	–
Sarcopenia (*n*. %)	18 (11.2%)	–	–	–
Sit to Stand App Variables[b]				
Time (s)	0.683	0.14	0.45	1.26
Velocity (m/s)	0.559	0.12	0.30	0.89
Power (W/Kg)	5.216	1.01	1.83	7.43

Appendicular Skeletal Muscle Mass (ASMM); Short Physical Performance Battery (SPPB). [a]Data are reported as median and interquartile range. [b]Values obtained from *Sit to Stand* App running on Android OS

observations were analyzed by one rater for intra-rater analysis and 322 observations were analyzed by the other rater for inter-rater and test–retest analysis. Both raters were physiotherapists with 8 and 13 years of clinical experience. However, they did not use the App in their routine clinical practice.

Objective 1—concurrent validity: Android App versus Apple App

Pearson's correlation coefficients revealed a very strong relationship between the Android App assessed variables for sit-to-stand time ($r = 0.92$; 95% CI: 0.89–0.94; $P < 0.001$), sit-to-stand velocity ($r = 0.95$; 95% CI: 0.93–0.96; $P < 0.001$), and sit-to-stand power ($r = 0.93$; 95% CI: 0.91–0.95; $P < 0.001$) and those derived from the Apple App (Fig. 3). Additionally, there was strong agreement between sit-to-stand time ($ICC_{2\text{-}1}$: 0.91; 95% CI: 0.88–0.94; $\alpha = 0.96$), sit-to-stand velocity ($ICC_{2\text{-}1}$: 0.94; 95% CI: 0.91–0.96; $\alpha = 0.97$), and sit-to-stand power ($ICC_{2\text{-}1}$: 0.93; 95% CI: 0.9–0.95; $\alpha = 0.97$) assessed with the Android and the Apple App. The coefficients of variation were as follows: 6.3%, 5.1%, 5% for sit-to-stand time, velocity, and power, respectively. Only 6 from a total of 161 observations were out of the limits of agreement. The measurements error (MAPE) for sit-to-stand time, velocity and power were 5.3, 4.8, and 5%, respectively.

Objective 2—intra-rater, inter-rater, and test–retest reliability

There was strong agreement between the measurements taken by the same rater within one week apart for sit-to-stand time ($ICC_{2\text{-}1}$: 0.97; 95% CI: 0.96–0.98; $\alpha = 0.99$), sit-to-stand velocity ($ICC_{2\text{-}1}$: 0.98; 95% CI: 0.97–0.98; $\alpha = 0.99$), and sit-to-stand power ($ICC_{2\text{-}1}$: 0.98; 95% CI: 0.97–0.99; $\alpha = 0.99$). Similarly, there was strong agreement between the two raters for sit-to-stand time ($ICC_{2\text{-}1}$: 0.97; 95% CI: 0.96–0.98; $\alpha = 0.99$), sit-to-stand velocity ($ICC_{2\text{-}1}$: 0.98; 95% CI: 0.97–0.98; $\alpha = 0.99$), and sit-to-stand power ($ICC_{2\text{-}1}$: 0.98; 95% CI: 0.97–0.99; $\alpha = 0.99$). Furthermore, excellent test-rest reliability was found between the two repetitions performed 30 min apart for sit-to-stand time ($ICC_{2\text{-}1}$: 0.86; 95% CI: 0.81–0.90; $\alpha = 0.93$), sit-to-stand velocity ($ICC_{2\text{-}1}$: 0.91; 95% CI: 0.87–0.93; $\alpha = 0.95$), and sit-to-stand power ($ICC_{2\text{-}1}$: 0.90; 95% CI: 0.87–0.92; $\alpha = 0.95$). The MDC_{95} for sit-to-stand time, velocity and power was 0.152 seg (22%), 0.101 m/s (18.3%), and 0.895 W/Kg (17.3%).

Objective 3—discriminant validity: physical performance measures and sarcopenia

A total of 18 (11.2%) from 161 older adults were classified as sarcopenic, whereas 25 (15.5%) were classified as low physical performance and 23 (14.3%) showed a reduced gait speed (Table 1). Older adults classified either as sarcopenic, low physical performance, or low usual gait speed showed higher sit-to-stand times and lower velocity and power values than their respective counterpart with large effect sizes (Hedges' g: > 0.8). The probability of a random observation from the healthy groups being better than a randomly selected observation from the non-healthy groups was in range of 73% to 80%. Additionally, the variables derived from the Android App showed an acceptable to excellent

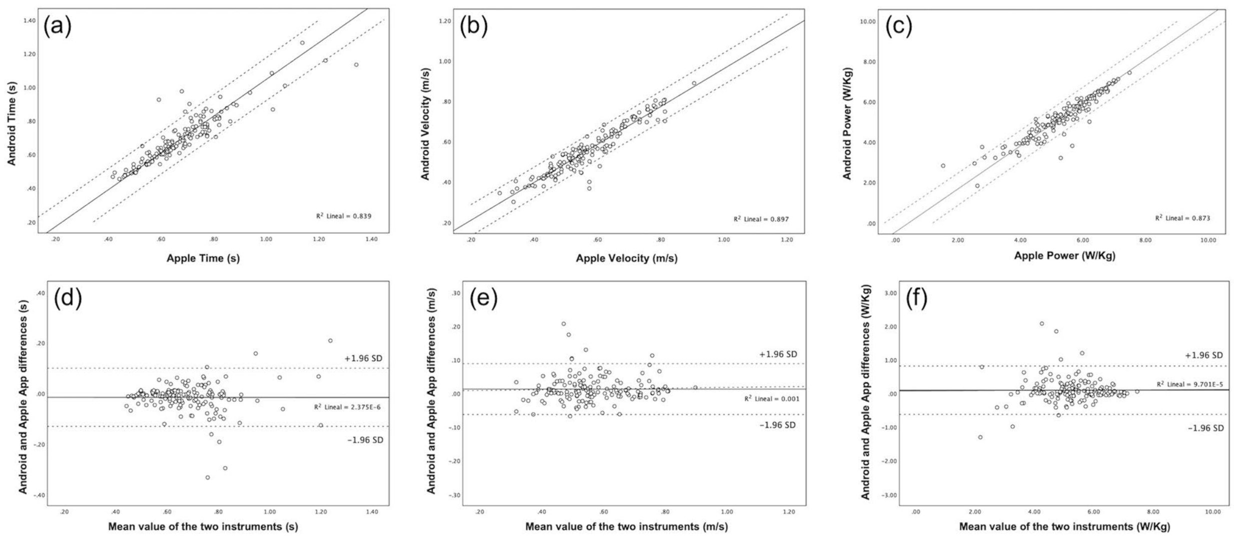

Fig. 3 Coefficient of determination for the *Sit to Stand* App running on Apple and Android OS for rising time (**a**), vertical velocity (**b**) and vertical power (**c**). Bland–Altman plots reflect the differences for rising time (**d**), vertical velocity (**e**) and vertical power (**f**) for the *Sit to Stand* App running on Apple and Android OS. The horizontal thin line represents the systematic bias while the dashed line represents the ± 1.96 standard deviations (SD)

ability to identify low usual gait speed, low physical performance, and sarcopenic older adults (AUCs ranged from 0.73 to 0.82) (Table 2).

Discussion

The aims of this study were to ascertain whether a new Android video analysis based-App is comparable to the previously validated Apple App, to determine its reliability, and to analyze the discriminant validity of the new App to differentiate people with sarcopenia, low gait speed and low physical performance with their respective counterpart. The results from this study showed excellent reliability and strong agreement for kinetic and kinematic variables derived from the App running on different OS. Moreover, these variables demonstrated acceptable to excellent validity to identify community-dwelling older adults classified as sarcopenic, low usual gait speed and low physical performance.

The consensus to determine the validity of consumer wearable and smartphone Apps evokes the need to systematically and transparently develop validation processes to ensure the use of this technology in a reliable and safe way [28]. However, there is still limited evidence about how the

Table 2 Discriminant validity: Areas under the curve (AUC) of the receiving operating characteristic and between-group comparison of the *Sit to Stand* App variables running on Android OS ($n = 161$)

	Low Usual Gait Speed (< 1 m/s)			Low physical performance (SPPB < 10 points)			Sarcopenia		
	Mean diff. (95% CI)	Hedges' *g* (CLES)	AUC (95% CI)	Mean diff. (95% CI)	Hedges' *g* (CLES)	AUC (95% CI)	Mean diff. (95% CI)	Hedges' *g* (CLES)	AUC (95% CI)
STS Time (s)	0.141 (0.08 to 0.2)	1.04 (0.73)	0.75 (0.66 to 0.86)	0.137 (0.59 to 0.21)	1.02 (0.74)	0.76 (0.65 to 0.86)	0.149 (0.08 to 0.22)	1.07 (0.74)	0.75 (0.63 to 0.86)
STS Velocity (m/s)	− 0.118 (− 0.16 to − 0.08)	1.05 (0.8)	0.81 (0.72 to 0.89)	− 0.107 (− 0.15 to − 0.06)	0.96 (0.75)	0.79 (0.70 to 0.88)	− 0.1 (− 0.16 to − 0.04)	0.85 (0.75)	0.74 (0.64 to 0.85)
STS Power (W/Kg)	− 1.114 (− 1.5 to − 0.7)	1.19 (0.8)	0.82 (0.73 to 0.90)	− 1.021 (− 1.47 to − 0.57)	1.08 (0.78)	0.79 (0.71 to 0.87)	− 0.878 (− 1.36 to − 0.39)	0.88 (0.73)	0.73 (0.63 to 0.83)

Between-group mean difference (mean diff.); Sit-to-Stand (STS); Short Physical Performance Battery (SPPB); 95% Confidence Interval (95% CI); Common Language Effect Size (CLES) validity of these Apps can be affected when different OS are used. From our knowledge, only one study [19] aimed to assess the validity of four commercially available step count and distance travelled based-Apps running simultaneously on Apple and Android OS. Their results showed considerable differences in measurement errors (MAPEs) for the four Apps running on different OS. In fact, the widely downloaded Argus App showed MAPE for distance travelled of 18% and 35% when the App was used on Apple and Android OS, respectively. Therefore, a previously validated App designed for a specific OS might not be valid running on a different OS and a validation process should be required prior to recommend its use.

The *Sit to Stand* App running simultaneously on Apple and Android OS showed extremely low levels of measurement error (MAPE $\leq$ 5%) [28] and excellent levels of reproducibility, either intra- and inter-rater reliability ($ICC_{2\text{-}1} \geq 0.97$), similar to those reported when the App was running on Apple iOS [9]. These results suggest that App's usability is equivalent between OS and the outcomes derived from the *Sit to Stand* App are not affected by differences between Apple and Android OS. This is noteworthy as previous studies [29, 30] aimed to validate smartphone video analysis based-Apps (similar to *Sit to Stand* App) on two identical smartphone devices running Apple iOS have shown coefficient of variations up to 10.4% between devices despite an excellent intra-rater reliability. These results were named as inherent technical error (*i.e.,* the agreement between two devices from the same model and brand). Considering these results, one would expect a higher coefficient of variation derived from the *Sit to Stand* App since it was working on different smartphone devices running Apple and Android OS. However, our results showed a coefficient of variations < 10% for kinetic and kinematic variables derived from the App highlighting its compatibility between OS.

Kinetic and kinematic variables derived from the sit-to-stand test such as time, velocity and power have been widely associated with several measures of physical function in older adults [9–11, 15]. These variables have also demonstrated their potential to discriminate between apparently healthy older adults to those with a history of falls, sarcopenia or even frailty [4, 10, 12–14]. However, these analyses have been usually performed through specialized equipment in a laboratory setting which requires technical expertise and are time-consuming to analyze limiting their potential to be used in clinical settings. Our results derived from the Android App showed an acceptable to excellent validity to discriminate between community-dwelling older adults classified as sarcopenic, low gait speed and low physical function compared to their respective counterpart. These results are similar to those reported by previous studies using force plates, linear encoders and inertial measurement units (Hedges' g: > 0.8) [4, 10, 12, 13] but with the advantage of an easy-to-use interface and automatic data processing from the App after video analysis which allows the clinicians to obtain kinetic and kinematic parameters in short-time periods emphasizing its clinical validity.

Although in a clinical setting the sit-to-stand transition is usually measured using a stop-watch, measurement errors from manual recordings are greater compared to more sophisticated wearable technology [18]. Moreover, kinetic variables such as vertical velocity or power were more sensitive to detect age-related functional decline [9] and to discriminate between older adults classified as sarcopenic, frail or poor physical performance compared to the time to complete the test, even when it was recorded through sophisticated technologies [12, 13, 18]. Additionally, vertical velocity and power have shown a higher responsiveness to detect exercise training effects than the time to complete the test or other clinical measures such as isometric quadriceps strength, timed-up and go and Berg balance scale [17]. However, vertical velocity or power can only be calculated from the rising phase of the test, *i.e.,* when the body loses contact with the seat and the center of mass is lifted until the full extension of the hip and knee joint [3, 31, 32], which is unviable to be collected using a stop-watch. Otherwise, calculating vertical velocity and power from the time to complete the test instead of from the rising phase would lead to underestimation up to ~ 62% of these variables [3, 33] since it would take into account the preparatory phase when trunk is accelerated forward prior to seat-off, and the stabilization phase just after the rising phase when the hip extension velocity reached zero and the stance of the body is achieved in a quasi-static balance way [3, 31, 32]. Thus, vertical velocity and power as well as the rising time can be easily and reliably detected in short time periods (< 5 min) without the need for specialized personnel and instrument using the *Sit to Stand* App running on Apple and Android OS.

Despite these promising results, this study is not without limitations. First, the study was performed in community-dwelling older adults from an elderly social center where physical activities were encouraged as can be observed in their levels of physical activity (median: 2356 MET-min·week^{-1}). Therefore, these results could not be inferred from mobility-limited older adults. In fact, the App was created for early detection of age-related functional impairments in clinical practice, so the ability to differentiate community-dwelling older adults classified as reduced gait speed, low physical performance and sarcopenic from their respective counterpart is a strength of this study. Second, due to the low prevalence of participant classified as a low gait speed, low physical performance and sarcopenic a discriminatory analysis categorized by sex could not be performed. Finally, muscle quantity was assessed by bioelectrical impedance analysis due to its portability, however, it is not recognized as the gold standard for the assessment of this variable. To overcome this limitation, a cross-validated equation in a sample with similar characteristics was used as previously recommended [22, 24, 34].

Conclusion

The present study showed that the new *Sit to Stand* App running on Android OS is comparable to the previously validated Apple App and demonstrated excellent reliability. Moreover, the variables derived from the App exhibited acceptable to excellent ability to identify community-dwelling older adults classified as sarcopenic, low usual gait speed and low physical performance. Further studies should analyze the App's responsiveness to an exercise intervention such as resistance training in older adults to identify its potential for rehabilitation monitoring.

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Data availability All data generated or analyzed during this study are included in this article. Datasets may be made available to editors, reviewers, and readers upon request to the corresponding author.

Declarations

Conflict of interest The authors have no conflicts of interest to declare.

Ethics approval This study protocol was reviewed and approved by the Ethical Committee of the Catholic University of Murcia, approval number CE022108. All procedures conformed to the Declaration of Helsinki.

Informed consent Informed consent was obtained from the participants included in this study.

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