Validity and Test–Retest Reliability of a Smartphone App for Measuring Rising Time, Velocity, Power, and Inter-Limb Asymmetry During Single-Leg Sit-to-Stand Test in Female-Trained Athletes

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ABSTRACT

The aim was to determine the validity and test – retest reliability of the *Sit to Stand* App variables (rising time, vertical velocity, and power) for measuring single-leg sit-to-stand (STS) test compared to those derived from ground reaction force data. Twenty-seven female athletes performed the single-leg STS test over three consecutive sessions simultaneously recorded with a force plate and the smartphone app. Validity was assessed with Pearson's correlation coefficient, intra-class correlation coefficient (ICC), and percentage error. Reliability was assessed with the ICC. Almost perfect correlations ($r \geq 0.95$) and excellent agreement (ICC = 0.96–0.97) between the app and force plate measures with low percentage errors (≤7.3%) were found. The app showed good-to-excellent reliability (ICC = 0.88–0.92) with no differences in inter-limb asymmetry over three sessions. The app was highly valid and reliable for measuring single-leg STS performance. Practitioners can use this app to assess lower-limb performance in female athletes.

KEYWORDS

Lower extremity; mobile app; rehabilitation; reliability; symmetry

Introduction

Maintaining symmetry between the lower extremities is crucial for athletic performance in basic and complex movements (Atkins et al., 2016). Functional imbalances in lower extremity strength which refer to conditions that limit a person's coordination or ability to move, increase injury risk, hinder the execution of sport-specific movements, and prolong recovery after injury, such as after anterior cruciate ligament (ACL) reconstruction (Nielsen et al., 2020; Virgile & Bishop, 2021). Since strength and power are considered two of the most important physical qualities for athletic performance (Suchomel et al., 2016), regular assessment of inter-limb imbalance in these two physical qualities are commonly examined during rehabilitation to determine the individual's readiness to return to sport (Bishop et al., 2023). Furthermore, since females may be more prone to producing strength and/or power asymmetrically than males (Bailey et al., 2015), focusing on female athletes for investigating strength and/or power asymmetry could yield valuable insights for monitoring athletic performance and the rehabilitation process after a serious injury.

Laboratory-based devices, such as computer-assisted isokinetic dynamometers (Pereira et al., 2019) and force platforms (Hart et al., 2019) that provide ground reaction force (GRF) data, are considered the gold standard for multidimensional strength assessment and detecting functional force asymmetry. However, various factors (i.e., cost, technical expertise, and time consuming nature) mean that field-based tests are commonly used in practice (Bok & Foster, 2021). For example, single-leg hopping, single-leg vertical jump, and change of direction performance tests are frequently used to evaluate lower limb asymmetry and monitor return to play after injury (Bishop et al., 2023; Taylor et al., 2020). However, these field-based tests may be inappropriate for assessing inter-limb imbalances at an early stage of rehabilitation, where jumping or change of direction tests may be contraindicated (Buckthorpe & Della Villa, 2021).

The mechanics of the sit-to-stand (STS) movement provide a simple, efficient, and low-impact way to assess lower extremity performance (Jordre et al., 2013). Even though the bilateral STS test can be used to assess lower-limb asymmetry as early as four weeks after ACL reconstruction (Labanca et al., 2016), the single-leg STS test could potentially provide a more accurate representation of the inter-limb asymmetry, since the force is distributed exclusively on the tested leg (Bishop et al., 2018). The single-leg STS test has been used at 2 months post-ACL reconstruction for knee joint muscle strength and inter-limb asymmetry recovery (Kamiike et al., 2023). Moreover, reduced single-leg STS performance has been observed in individuals recovering from ACL injuries compared to healthy individuals (Nielsen et al., 2020). Using technological devices in the data collection process, rather than relying on manual recordings (i.e., stopwatches), can minimize potential measurement errors (Makaracı et al., 2023).

Smartphones are equipped with sophisticated hardware similar to those found in a laboratory setting, which provide the opportunity to develop smartphone apps for athletic performance assessment (Balsalobre-Fernández et al., 2019; Barbalho et al., 2020; Bishop et al., 2022). The *Sit to Stand* App is a free video-analysis based app created to analyze the rising phase of the bilateral STS movement via high-speed video recording. Thus, the users can identify accurately the beginning and the end of the rising phase selecting two video frames through an easy-to-use interface. Then, the App provides the time to rising and calculates automatically the vertical velocity based on vertical displacement and time and power through a previous validated regression equation (Ruiz-Cárdenas et al., 2018). Although, rising time, vertical velocity, and power derived from this app are complementary measures of physical performance, the importance of measuring velocity or power as variables independent from traditional STS time has been previously documented. This is mainly because each variable has shown different relationships with functional outcomes, age-related changes, and even different response to an exercise intervention (Glenn, Gray, & Binns, 2017; Glenn, Gray, Vincenzo, et al., 2017; Regterschot et al., 2014; Ruiz-Cárdenas et al., 2018). Rising time, vertical velocity, and power resulting from this app were highly valid compared to data derived from force plates and 3D motion capture camera during the bilateral STS test in older (Orange et al., 2020) and non-athletic mixed-gender samples with a very broad age range (i.e., 26–81 years) (Ruiz-Cárdenas et al., 2018). However, its validity and reliability are unknown during the single-leg STS test for trained athletes. If the application was valid, it could be a potential tool for monitoring inter-limb asymmetry and functional performance, especially in scenarios where there is a lack of equipment and time constraints.

Therefore, the aims of this study were to: (1) validate rising time, vertical velocity, and vertical power variables derived from the *Sit to Stand* App compared to those obtained from the force plate during the single-leg STS test, (2) determine the test – retest reliability of the App over three consecutive sessions 48 h-apart, and (3) analyze whether leg dominance influences the validity and reliability of the *Sit to Stand* App measures in female trained athletes. We hypothesized that variables derived from the *Sit to Stand* App would show good to excellent agreement with those obtained from the force plate during the single-leg STS test (hypothesis 1), these variables also would show at least good inter-session reliability (hypothesis 2), and would not be influenced by leg dominance (hypothesis 3).

Methods

Participants, recruitment, and sampling

Orange et al. (2020) previously reported a strong relationship between the *Sit to Stand* App and force plate when measuring power in the bilateral STS ($r = 0.74$; 95% confidence interval [CI]: 0.50–0.87). Twenty-three participants provide 80% power ($\alpha = 0.05$, one-sided) to detect a correlation of equal to or greater than the lower 95% CI in that study ($r \geq 0.5$). Twenty-seven uninjured female trained athletes (median age 21 years, interquartile range [IQR] 18–21.5, $n = 23$ right-limb dominant; $n = 4$ left-limb dominant) volunteered to participate in the present study. The dominant limb for each participant was determined as the leg they would use to kick a ball (Makaracı et al., 2023).

The participants were recruited from a state university's Faculty of Sport Sciences and a Sports High School affiliated with the Ministry of Education in Turkey. Therefore, they were familiar with strength and conditioning procedures and study protocols assigned to them. Inclusion criteria were: regularly participating in team or individual training at least three days a week and not having any musculoskeletal injuries/conditions. Exclusion criteria were: having undergone lower-limb surgery within the last six months, experiencing discomfort or pain during the test, and without having a period of premenstrual or menstrual phases. The baseline characteristics of the study participants are presented in Table 1.

The participants were informed about the risks and benefits of the study and provided their written informed consent prior to participation. Signed parental consent was obtained for participants younger than 18 years. Ethical approval for the study was granted by the Clinical Research Ethics Board of Karamanoğlu

Table 1. Participant characteristics ($n = 27$).

	Mean	SD	Minimum	Maximum
Age (years)[a]	21	(18–21.5)	16	23
Sports experience (years)[a]	7	(6–9)	5	11
Height (m)	1.64	6.2	1.54	1.78
Body mass (kg)	53.4	8.7	42	78
Body mass index ($kg \cdot m^{-2}$)[a]	19.36	(17.8–20.6)	16.53	27.64
Femur length (m)[a]	0.49	(0.47–0.52)	0.46	0.59
Sit to Stand App variables				
Rising time (s)[a]	0.794	(0.702–0.886)	0.483	1.192
Vertical velocity (m/s)	0.643	0.15	0.386	0.994
Vertical power (W/kg)	6.807	1.34	3.73	9.32
Force plate variables				
Rising time (s)[a]	0.748	(0.658–0.852)	0.542	1.197
Vertical velocity (m/s)	0.673	0.14	0.384	0.959
Vertical power (W/kg)	6.526	1.30	4.02	8.87

[a]Data reported as median and interquartile range due to absence of normality.

Mehmetbey University (Ethics approval no: 01–2023/21).

Study design and procedures

This study was designed to address the criterion validity and test–retest reliability of the *Sit to Stand* App variables (i.e., rising time, vertical velocity, and vertical power) for measuring single-leg STS performance in female athletes. Criterion validity evaluated by comparing the App variables with those derived from GRF data, while test – retest reliability was assessed over three consecutive sessions. Prior to the study measurements, participants underwent familiarization sessions for the single-leg STS movement pattern on two separate days. During the first visit to the laboratory (session 1), demographic and anthropometric information were collected, followed by the validity of the App. In addition, session 1, 2, and 3, with 48 hr apart, were used to assess the test – retest reliability of the *Sit to Stand* App. These measurements were conducted by the same researcher (KG, the third author of the study). Participants were instructed to refrain from consuming caffeine for at least 12 hr and from engaging in moderate-to-high intensity exercise for at least 24 hr prior to each session.

The single-leg STS test was performed using a portable force plate (Kistler, Winterthur, Switzerland; type 9260AA6; 1000 Hz). The signals from the force plate were transmitted to a laptop computer through a data acquisition board (type 5691A; Switzerland; USB 2.0) and recorded by Kistler's MARS. Then, the raw data was exported as a Microsoft Excel file for data analysis. In addition to the force plate measurements, the *Sit to Stand* App (lite version 1.0) running on an iPhone 14 Pro (Apple Inc., USA) was used to simultaneously capture video recordings of the single-leg STS performance. The App required the participants' femur length, which was determined at the first trial using a measuring tape (Ruiz-Cárdenas et al., 2018). The measuring tape placed alongside the femur bone, starting from the greater trochanter and extending to the lateral condyle when the participants lie on their back on a flat surface, with their legs extended and relaxed. Throughout the recording process, the smartphone was placed on a tripod at a height of 0.7 meters, positioned perpendicular to the sagittal plane, and 3 meters away from the force plate on the right or left side of the participant according to the lower limb assessed. Video recordings were captured at 240 frames per second and a quality of 1080 pixels.

Single-leg sit-to-stand test

Prior to the single-leg STS test, participants underwent a standardized 10-min warm-up, including active and passive stretching exercises, and practices of the single-leg STS. During the single-leg STS measurements, we followed the protocol used by Makaracı et al. (2023). The test started in a sitting position on a chair and the feet were placed on the unloaded plate. An adjustable chair was used to ensure that the participant's knee was flexed at a 90° angle and positioned on the center point of the force plate. Participants were instructed to rise as quickly as possible from the sitting position and achieve a standing posture with full knee extension using their preferred leg (tested leg) with their hands placed on their hips. If the trial was executed correctly, the measurement was automatically concluded by the force plate software. Otherwise, the participant would step off the force plate and return to the starting position on the unloaded plate, with 30 sec of rest. The test was performed for both the dominant and non-dominant legs. Three trials were performed on each leg and the best performance value in terms of test variables (i.e., rising time, vertical velocity, and vertical power) was used for further analysis. Each trial was separated by a 30 sec recovery period.

Data analysis

Video analysis from the *Sit to Stand* App was performed by one independent observer blinded to force plate outcomes. Following the App instructions, a visual sticker was placed on the greater trochanter of the participant for the identification of the rising phase. The beginning of this phase is defined when the visual sticker moved forward and upward to the following square on the screen of the App. The end of this phase is defined when the sticker achieves the highest vertical point (Figure 1). This time interval is defined as the rising time. Then, the App automatically calculates vertical velocity (m/s) as the vertical displacement over time and vertical power relative to body mass (W/kg) through the previously validated regression equation (Orange et al., 2020; Ruiz-Cárdenas et al., 2018, 2023):

$$\text{Vertical}\textit{al}\text{power}(\mathrm{W/kg}) = 2.773 - 6.228 \times t + 18.224 \times d$$

Where t is the rising time as calculated by the two selected frames and d is the femur length which is matched with the vertical displacement when the participant is sat at 90 degrees of knee joint.

To validate these measures, data from the force plate was calculated from the rising phase of the single-leg STS test as previously described (Laudani et al., 2014; Lindemann et al., 2003). In brief, the rising phase begins when the participant's buttocks left contact with the chair, which is time-matched when the peak of vertical GRF is achieved (McGibbon et al., 2004; Stevermer & Gillette, 2016). Then, vertical GRF decreases and increases again until body weight is reached which is time-matched when the knee is fully extended (Kralj et al., 1990). The time interval between these kinetic points was defined as the rising time. Finally, vertical velocity (m/s) and power (W/kg) relative to body mass were calculated as the vertical displacement over time and as the product of mean vertical GRF and velocity in this time interval, respectively.

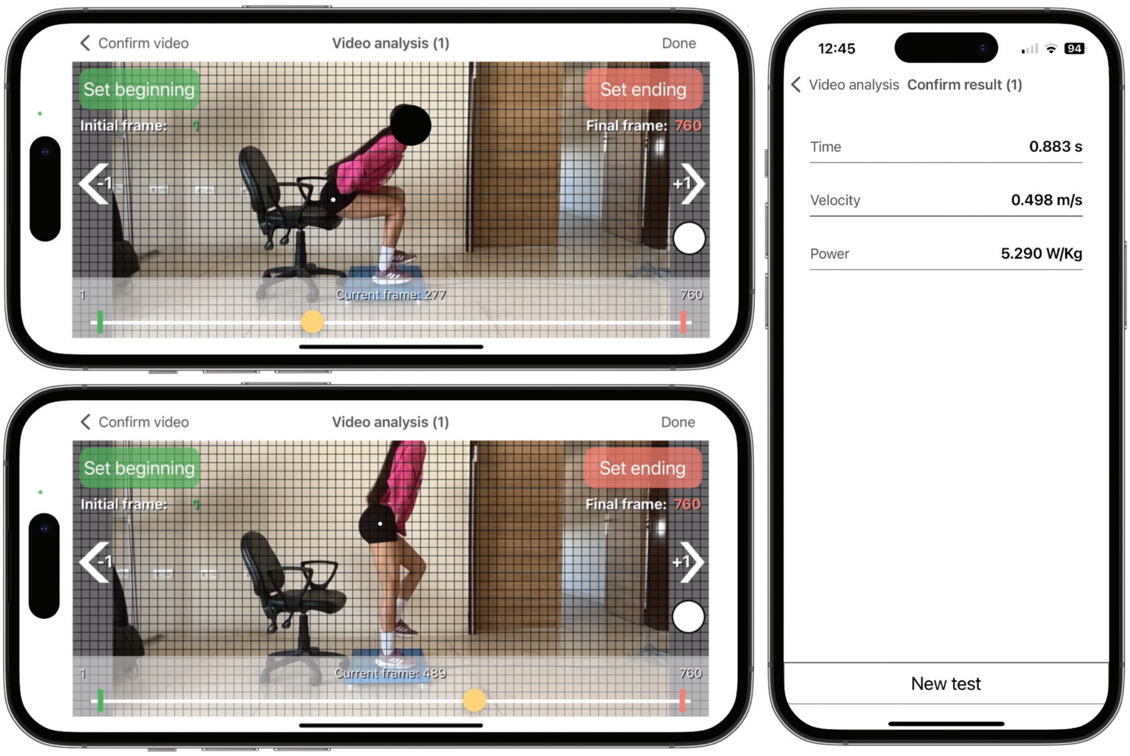

Figure 1. User interface of the *sit to stand* app running on an iPhone 14 pro. White dot represents the colored sticker placed on the greater trochanter at the beginning of rising phase when white dot crossed the first horizontal grip line on the screen (top panel) and at the end of the rising phase when white dot achieved the highest vertical point (lower panel). Example of a participant with 0.44 m of femur length and dominant leg execution.

Inter-limb asymmetry calculation

Inter-limb differences in rising time, vertical velocity, and power recorded by the *Sit to Stand* App were calculated using the formula proposed by Bishop et al. (2018):

$$(\text{Stronger limb} - \text{Weaker limb})/\text{Stronger limb} \times 100$$

Statistical analysis

Statistical analyses were performed using JASP software 0.17.1 (JASP Team, Netherlands). Rising time data from the force plate and the *Sit to Stand* application were log-transformed due to evidence of non-normality, as confirmed by the Shapiro – Wilks test. The level of statistical significance was set at $p \leq .05$.

To determine the criterion validity of the App variables (rising time, vertical velocity, and power) compared to the force plate data, Pearson's correlation coefficients (r) with 95% CIs was used to assess relationships between devices and interpreted as negligible (<0.1), small (0.1–0.29), moderate (0.3–0.49), high (0.5–0.69), very high (0.7–0.89), or almost perfect (≥0.9). Agreement between devices was assessed using mean differences and 95% limits of agreement and with the intra-class correlation coefficients ($ICC_{2\text{-}k}$) and Cronbach's alpha which was interpreted as poor (<0.5), moderate (0.50–0.74), good (0.75–0.89), and excellent (>0.9). Measurement errors were assessed using the mean absolute percentage error (MAPE, %). Finally, one-way ANOVA was used to analyze whether the validity of the measurements was influenced by leg dominance.

One-way repeated measures ANOVA was used to analyze the test – retest reliability of the *Sit to Stand* App variables, with leg dominance as an interaction effect. If significant main effects were observed, these were followed up by post-hoc Bonferroni-corrected pairwise comparisons. Cohen's d was reported as an estimate of effect size and interpreted as trivial (0–0.2), small (>0.2–0.6), moderate (>0.6–1.2), and large (>1.2). Since inter-limb asymmetry data was not normally distributed, the Kruskal–Wallis tests were used to determine differences in asymmetry between test sessions and the partial-eta squared was used as effect size and interpreted as small (0.01), moderate (0.06), and large (0.14). We also calculated $ICC_{2\text{-}k}$ to assess relative reliability. Additionally, the minimal detectable change with 95% confidence (MDC_{95}) was calculated as $SEM_{agreement} \times \sqrt{2} \times 1.96$.

Results

Validity: comparison between force plate-derived data and sit to stand app

Pearson's correlation coefficients revealed almost perfect correlations ($r \geq 0.95$) between the *Sit to Stand* App assessed variables for rising time, vertical velocity, and vertical power and those derived from the force plate (Figure 2 and Table 2). Additionally, there was excellent agreement ($ICC_{2\text{-}k} \geq 0.96$) between the App and force plate-derived data for rising time, vertical velocity, and vertical power. The mean absolute percentage error for rising time, vertical velocity, and vertical power were 7.3, 6.6, and 5.7%, respectively (Table 2). There was no influence of leg dominance on systematic bias for rising time ($F = .161$; $p = .69$), vertical velocity ($F = .51$; $p = .48$), and vertical power ($F = .723$; $p = .40$).

Test – retest reliability: comparison of sit to stand app variables between three consecutive sessions

The repeated measures ANOVA showed a significant time effect for rising time (F = 3.471; $p = .03$), vertical velocity (F = 4.001; $p = .02$), and vertical power (F = 3.471; $p = .03$) over three consecutive sessions. Post-hoc pairwise comparisons revealed better performance for all *Sit to Stand* App variables during session-3 compared to session-1 ($p < .05$), however these differences were small ($d = 0.2$) and clinically inconsequential (Table 3). Additionally, no differences were found between session-1 and session-2 or session-2 and session-3.

There was good to excellent reliability between rising time ($ICC_{2\text{-}k}$: 0.88; 95% CI: 0.81–0.93; α = 0.89), vertical velocity ($ICC_{2\text{-}k}$: 0.88; 95% CI: 0.81–0.93; α = 0.89), and vertical power ($ICC_{2\text{-}k}$: 0.92; 95% CI: 0.87–0.95; α = 0.92) during three consecutive sessions. Test – retest reliability was not significantly influenced by leg dominance for any of the *Sit to Stand* App variables. Moreover, no significant differences were found for inter-limb asymmetry during three consecutive sessions for any of the App variables ($p > .05$) (Table 3). The minimal detectable change (MDC_{95}) of the *Sit to Stand* App during three consecutive sessions was .179 s, .136 m/s, and .165 W/kg, for rising time, vertical velocity, and vertical power, respectively.

Discussion

Our novel findings indicated that the *Sit to Stand* App was a valid and reliable tool for measuring rising time,

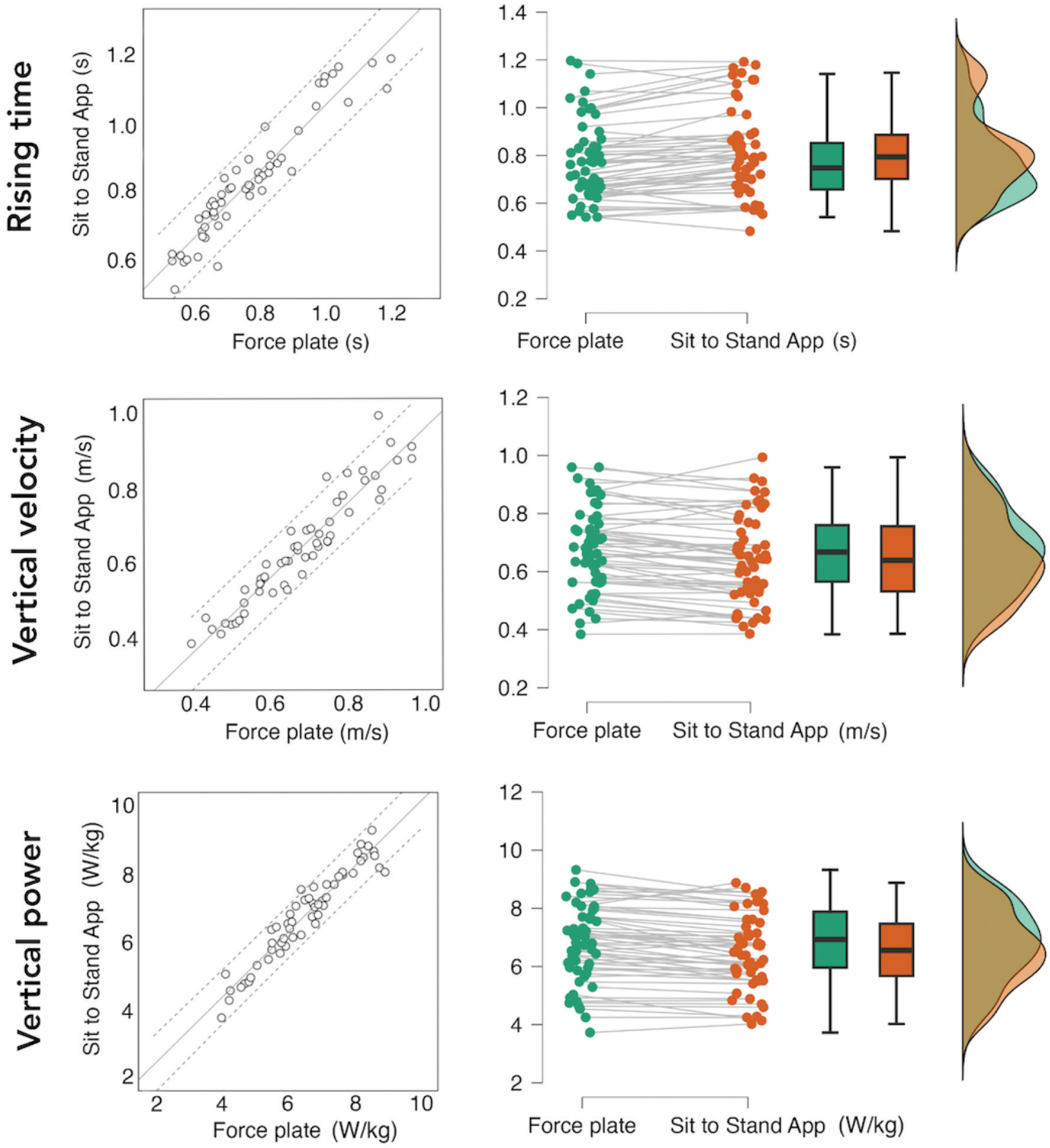

Figure 2. Pearson's correlation coefficients (left panels) and individual errors (right panels) between the *sit to stand* app and the force plate for rising time (s), vertical velocity (m/s), and vertical power (W/kg).

Table 2. Comparison between force plate and *sit to stand* app variables for both legs.

	Mean bias (±1.96 SD)	*r*-coefficient (95% CI)	MAPE (95% CI)	$ICC_{2\text{-}k}$ (95% CI)
Rising time (s)	−0.040 (−0.075 to 0.155)	0.94 (0.91 to 0.97)	7.3 (5.9 to 8.7)	0.96 (0.87 to 0.98)
Vertical velocity (m/s)	−0.030 (−0.121 to 0.061)	0.95 (0.92 to 0.97)	6.6 (5.4 to 7.8)	0.96 (0.89 to 0.98)
Vertical power (W/kg)	0.281 (−0.470 to 1.032)	0.96 (0.93 to 0.98)	5.7 (4.4 to 7.0)	0.97 (0.88 to 0.99)

Data are reported as mean bias ±1.96 standard deviation (SD), 95% confidence interval (95% CI), mean absolute percentage error (MAPE), intra-class correlation coefficient ($ICC_{2\text{-}k}$).

vertical velocity, and vertical power during the single-leg STS test in female athletes. Additionally, the validity and reliability of the App was not affected by leg dominance. These results suggest that the App is a valuable tool for assessing lower extremity performance during the single-leg STS test and identifying potential imbalances in trained female athletes.

The *Sit to Stand* App was originally created and validated to assess rising time, vertical velocity, and power during the traditional (bilateral) form of the

Table 3. Comparison between three consecutive sessions for *sit to stand* app variables.

	Session-1 vs. Session −2			Session −2 vs. Session −3			Session −1 vs. Session −3			Asymmetry (%)			
	Mean bias	95% CI	Cohen's d	Mean bias	95% CI	Cohen's d	Mean bias	95% CI	Cohen's d	Session −1 Mean (SD)	Session −2 Mean (SD)	Session −3 Mean (SD)	Partial eta-squared
Rising time (s)	0.022	(−0.02 to 0.07)	0.11	0.029	(−0.02 to 0.08)	0.15	0.05	(0.01 to 0.1)	0.26	11.5 (8.1)	13.1 (9.8)	11.7 (7.1)	0.01
Vertical velocity (m/s)	−0.028	(−0.06 to 0.01)	0.19	−0.012	(−0.05 to 0.01)	0.08	−0.04	(−0.07 to −0.01)	0.27	11.5 (8.1)	13.1 (9.8)	11.7 (7.1)	0.01
Vertical power (W/kg)	−0.135	(−0.42 to 0.16)	0.09	−0.179	(−0.47 to 0.11)	0.13	−0.314	(−0.60 to −0.02)	0.23	8.98 (6.6)	11.6 (13.1)	8.8 (7.1)	0.03

Data are reported as mean bias with 95% confidence interval (95% CI) or mean and standard deviation (SD). Intra-class correlation coefficient ($ICC_{2\text{-}k}$). All comparisons were adjusted by Bonferroni.

STS test aiming at monitoring disease- and age-related functional performance (Martínez-García et al., 2020; Orange et al., 2020; Ruiz-Cárdenas et al., 2018). However, the use of this App for assessing single-leg STS performance has not been previously evaluated. Our results expand the App application beyond its typical use for elderly and individuals with chronic disease to a population of trained female athletes highlighting its potential for assessing sport-related activities and inter-limb asymmetry. The feasibility of previously validated Apps such as *My Jump2 or COD timer* (Balsalobre-Fernández et al., 2019; Barbalho et al., 2020; Bishop et al., 2022) with high mechanical demands could be compromised for monitoring inter-limb asymmetry in the early stages of injury (Buckthorpe & Della Villa, 2021). In this context, the *Sit to Stand* App may offer a unique perspective in assessing lower limb performance and symmetry in the early phases of rehabilitation compared to other validated tests, such as the unilateral hopping, countermovement jump, or drop jump (Davies et al., 2020). Nevertheless, the validity and feasibility of this App in injured athletes should be tested prior to recommend its use. Laudani et al. (2014) analyzed inter-limb asymmetry using two force plates during the traditional form of the STS test (bilateral) in patients at one month after ACL reconstruction and in healthy-controls. The test was feasible at an early-stage post-surgery and showed greater inter-limb asymmetry in vertical GRF_{peak} in patients than healthy-controls (33% versus 5%). In our study, inter-limb asymmetries were greater and ranged between ~9% to 12%, depending on the outcome, in healthy trained female athletes. These discrepancies might be attributed to the type of the test used. While the single-leg STS test forces the individual to distribute the force exclusively on the tested leg, the traditional form of the STS test allows force distribution between both legs. This latter could inform us about a protector mechanism, avoiding the body weight distribution on the affected leg, rather than providing a true measure of performance. Thus, unlike the traditional form of STS test, the single-leg STS test could potentially provide a more accurate representation of the inter-limb asymmetry, since no contribution exists from the opposing limb (Bishop et al., 2018; Thongchoomsin et al., 2020).

Recent studies have shown the validity of the single-leg STS test for assessing time to complete five repetitions (Thongchoomsin et al., 2020; Waldhelm et al., 2020) and maximum repetitions performed in 30 sec using a stop-watch in healthy individuals (Waldhelm et al., 2020). Given the importance of lower-limb strength and power for athletic populations (Suchomel et al., 2016), the assessment of asymmetry for these physical capacities seems especially relevant (Bishop et al., 2023). Leg dominance in sports, especially in female athletes, can lead to the development of unilateral lower limb damage that is frequently manifested as an ACL injury. Moreover, in various sports (team/individual and limited-contact/noncontact), female athletes had a higher risk of ACL injuries than male athletes (Morishige et al., 2019). When considering the ACL injury process (rotational landing, stiff-legged landing), limb asymmetry emphasizes the neuromuscular deficiencies that female athletes usually exhibit (Montalvo et al., 2019). The single-leg STS was reported as a feasible exercise during the rehabilitation period at an early stage following ACL reconstruction and it also demonstrated improved knee muscle strength and limb asymmetry as measured with an isokinetic device (Kamiike et al., 2023).

Our findings showed almost perfect correlations, excellent reliability, and acceptable MAPE between the App and force plate variables during the single-leg STS performance regardless of leg dominance. These findings highlight the potential use of the *Sit to Stand* App in field-based settings and clinical rehabilitation programs where rapid user-friendly and cost-free instruments are essential. Even though limb dominance profiles are inconsistent in athletes, functional limb imbalances are still related to repeated sprint ability and athletic performance (Virgile & Bishop, 2021). In addition, Makaracı et al. (2023) provides further insights by demonstrating a positive correlation between single-leg STS and countermovement jump performance. This suggests that performance in the single-leg STS test may have implications for other functional movements and athletic capabilities. Our findings show that the leg dominance also does not affect the validity and reliability of the App variables compared to the force plate. There was good to excellent agreement between rising time, vertical velocity, and vertical power during three consecutive sessions (ICCs = 0.88–0.91). On the other hand, post-hoc pairwise comparisons revealed better performance for all *Sit to Stand* App variables on session-3 compared to session-1, which may be attributed to a learning effect. However, the difference between the two sessions was minimal (d = 0.2). Moreover, no differences were shown on inter-limb asymmetry on three consecutive sessions. These findings could be attributed to the potential role of the App for detecting possible limb asymmetry.

Strength and limitations

This is the first study investigating the validity and test – retest reliability of the rising time, vertical velocity, and power variables during the single-leg STS in trained female athletes. The study findings show an excellent validity for those variables compared to a more sophisticated device, making the App a practical and accessible tool, particularly for clinical researchers. However, there are limitations to consider. Since this study is the first attempt to examine the reliability of the App for the single-leg STS in female uninjured trained athletes, the results may not be generalizable to individuals who are in a rehabilitation program for sports injuries. Further research is needed to validate the App's variables in those specific populations. Additionally, for a convergent validity assessment of the App variables, the use of a valid performance test specifically targeting the lower extremities would be beneficial.

Conclusion

The *Sit to Stand* App was highly valid and reliable for measuring rising time, vertical velocity, and vertical power, compared with those determined by a force plate, regardless of leg dominance, in trained female athletes. Therefore, in the absence of more sophisticated equipment, this App may be a reliable and useful clinical option to assess lower-limb functional performance and detect lower-limb asymmetries for female athletes.

Acknowledgments

The authors thank all the student-athletes who volunteered their time to participate in this study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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