Test-Retest Reliability and Convergent Validity of Piezoelectric Force Plate Measures of Single-Leg Sit-to-Stand Performance in Trained Adults

Running head: Reliability of the single-leg sit-to-stand test

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ABSTRACT

The single-leg sit-to-stand (STS) test has emerged as a promising method of assessing lower-limb functional strength and asymmetry. However, the reliability of its performance parameters on a force plate has not been explored. This study examined the test-retest reliability and convergent validity of the single-leg STS test performed on a piezoelectric-based force plate in trained participants. Thirty trained male adults (age: 21.4±1.7 years) performed three separate single-leg STS days of testing to assess both intra- and inter-day reliability. Performance parameters included STS time, ground reaction force (GRF), and center of pressure (CoP) sway velocity. The relationship between single-leg STS parameters and unilateral counter-movement jump (CMJ) variables was assessed for convergent validity. Intra-class correlation coefficients (ICC) and coefficient of variation (CV) were calculated for reliability analyses and convergent validity was assessed with Spearman's correlation coefficient (ρ). In the dominant leg, single-leg performance parameters showed moderate to excellent intra-day reliability (ICC=0.65-0.90, CV=4.3-11.2%) and moderate inter-day reliability (ICC=0.54-0.74, CV=5.8-13.5%). In the non-dominant leg, all single-leg STS performance parameters showed good intra-day (ICC=0.79-0.86, CV=3.8-9.8%) and inter-day reliability (ICC=0.75-0.82, CV=4.6-9.7%). STS times in the dominant and non-dominant legs were inversely related to unilateral CMJ velocity (ρ=-0.47 and -0.38, respectively). CoP sway velocity in the non-dominant leg showed positive correlations with unilateral CMJ power and velocity (ρ=0.38 and 0.54, respectively). In conclusion, the force plate-based single-leg STS test provides reliable measures of STS time, GRF, and CoP sway velocity in trained adults, and could be used to assess lower-limb function and asymmtery.

Keywords: reliability, validity, functional strength, kinetic chain, limb symmetry index, lower extremity, unilateral jump

INTRODUCTION

Weakness or strength imbalances in the lower limbs may affect fundamental athletic tasks that are required in most field sports, such as jumping, running, and change of direction (8). Functional limb imbalances are negatively associated with an individual's repeated sprint ability and athletic performance (43) and influence return to play times after lower-limb injury (19). Following unilateral lower limb injuries, athletes usually show lower-limb strength asymmetry (12) and a strength discrepancy of more than 10-15% between the lower extremities is thought to represent problematic asymmetry (14). Unilateral strength and power-based tests, such as maximal jumps and repeated jumps, are often used to characterize lower limb functional ability and quantify limb asymmetries (37).

Variations in jump height and ground reaction force (GRF) impulse between right and left legs in the single-leg counter-movement jump (CMJ) are indicatve of functional strength asymmetries and hence, it is recommended that the single-leg CMJ is used when examining strength asymmetry in the lower limbs (5). Similarly, the single-leg sit-to-stand (STS) test is a functional test used to determine unilateral lower-limb strength (especially the quadriceps) and strength imbalances (1). As a closed-kinetic chain movement, using the single-leg STS test to assess potential lower-limb strength asymetries may be particularly beneficial in the context of rehabilitation after lower-limb injury where single-leg jumping may be contraindicated, for example, following anterior cruciate ligament reconstruction (28). Whilst previous research has shown that bilateral (25, 26) and single-leg (39) STS performance is related to lower-limb strength, the relationship between single-leg STS parameters and single-leg CMJ performance has not been explored. The single-leg STS also replicates the unilateral-nature of running, and thus may be more reflective of lower-limb functional ability in trained athletes than bilateral tests, such as the CMJ or back squat. However, the use of the single-leg STS test to assess lower-limb function and assymetry is contingent on the reliability and validity of its performance parameters, such as STS time, GRF, and center of pressure (CoP) away velocity.

In a recent study by Waldhelm et al. (44), the single-leg STS test was shown to be highly reliable (intraclass correlation coefficients [ICC]: 0.87 to 0.99) in two separate protocols (maximum repetitions in 30 seconds; duration of five regular repetitions). Similarly, Thongchoomsin et al. (39) reported excellent test-retest reliability of the single-leg STS test (time taken to complete five repetitions; ICC = 0.96) and moderate to good convergent validity related to isokinetic lower extremity muscle strength (r = -0.43 to -0.71). However, given that the data were collected manually, it is highly likely that human error was introduced into the overall estimate of measurement error. Force plates, which are increasingly used in the field of sports sciences, were designed to perform axial force-centered biomechanical and posturographic measurements of the person using sensing technology such as piezoelectricity. Piezoelectric measurement technology provides highly-accurate measurements by producing an electrical charge proportional in magnitude to the applied force (4). The assessments of between-limb differences based on the force-time curve are considered a valid and practically accessible method for athletes from different sports (16). In this context, parameters such as GRF (31) and CoP postural sway applied by the person's leg during rising (17) can be examined by performing the single-leg STS test on the force plate. These performance parameters provide valuable data above STS time alone. For example, unilateral postural stability is necessary for controlling voluntary movements in sports and is associated with reduced injury risk (32). Furthermore, obtaining single-leg STS time via a force plate rather than a manual assessment reduces the contribution of human error to the total measurement error between test-retest trials. In fact, force plate measurements are considered the "gold standard" in recording some commonly used athletic test data (i.e., CMJ, postural sway) (9, 45).

To our knowledge, no study has examined the test-retest reliability of the single-leg STS test in trained adults. Single-leg STS performance parameters, such as STS time, GRF and CoP sway velocity, may provide valuable insights into lower-limb functional strength and asymmetries in athletes. Therefore, the main aim of the study was to evaluate the test-retest (intra-day and inter-day) reliability of the single-leg STS test performed on a piezoelectric-based force plate in trained participants. Furthermore, we aimed to test the convergent validity of the single-leg STS test by assessing its relationship with single-leg CMJ performance, which is a recommended test for evaluating lower-limb strength asymmetry in athletes. We hypothesized that force plate-based measures of single-leg STS performance would show at least moderate reliability (ICC > 0.50) in trained adults and significantly correlate with single-leg CMJ performance variables.

METHODS

Experimental Approach to the Problem

A repeated measurements design was used to evaluate the reliability (intra-day and inter-day) of the single-leg STS test performed on a piezoelectric-based force plate in trained individuals. Three single-leg STS trials were undertaken on day 1 to evaluate intra-day reliability. Single-leg STS trials were then repeated on day 2 and day 3, with at least three days of rest in between each day of testing, to evaluate inter-day reliability. In addition, the single-leg CMJ (dominant and non-dominant leg) tests were conducted following the last trial of single-leg STS on day 1 to assess convergent validity.

An anti-slip textured finish portable force plate (Kistler, Winterthur, Switzerland; type 9260AA6; 600x500x50 mm; natural frequency ≈ 400 Hz) was used for single-leg STS and CMJ measurements. The signals received from the force plate were transferred to a laptop computer (HP Probook 450 G6 with Core i7) through a data acquisition board (type 5691A; Switzerland; USB 2.0) and BioWare software and saved as a Microsoft Excel (Microsoft Corp., Redmond, WA, USA) file. The test parameters related to the single-leg STS and CMJ were obtained using Kistler's Measurement, Analysis & Reporting Software (MARS) (Kistler MARS, S2P Ltd., Ljubljana, Slovenia) which is commercially available (35).

Before the study measurements, participants were shown single-leg STS and CMJ movements in the appropriate form accepted by the force plate. All measurements were standardized by asking each participant to do at least two correct repetitions (familiarisation), with the technique adjusted if necessary. Participants used their own running shoes in all measurements performed on the force plate. Participants' caffeine consumption (≥ 12 hours) and participation in moderate- to high-intensity exercise (≥ 24 hours) were restricted before each session. Moreover, it was ensured that participants continued their habitual diets and we encouraged them to consume adequate fluids on testing days.

Subjects

Thirty uninjured male trained adults (age 21.4 ± 1.7 years, n = 28 right-limb dominant; n = 2 left-limb dominant) voluntarily participated in the study. The subjects were recruited from the Faculty of Sport Sciences at a state university and all were familiar with strength and conditioning procedures. Age range of participants was 19 to 26 years. The dominant limb of the subjects was identified as the leg that would be used to kick a ball (42). All participants regularly attended individual or team training sessions (≥ 3 times per week) in addition to practical courses in the Faculty (involving team and individual sport training 2 times per week). Thus, the participants are considered "trained adults" according to the participant classification in training and performance specified by McKay et al. (22). The baseline characteristics of the study participants are presented in Table 1.

INSERT TABLE 1 HERE

The criteria for inclusion in the study were age ≥ 18 years, having no musculoskeletal injury, not smoking, and regularly participating in team or individual training at least three days a week. The criteria for exclusion from the study were having pain during the test, having a lower-limb disability, or having undergone lower limb surgery in the last six months. All subjects were fully informed about the experimental procedures (the duration of each session, the type of athletic tests, and potential risks) and provided their verbal and written informed consent prior to participation. This research was approved by the ethical review board of Karamanoğlu Mehmetbey University (Approval ID: 05-2022/102).

Procedures

Test-retest sessions

Intra-day measurements of the single-leg STS test were performed in three different trials in the morning (9 am to 11 am), at noon (1 pm to 3 pm), and evening (5 pm to 7 pm) on day 1. The inter-day measurements of the single-leg STS test were carried out on day 2 and day 3, with a three-day break in betweendays of testing. . The measurements on day 2 and day 3 were collected at noon hours (1 pm to 3 pm).

Single-leg sit-to-stand test

Before starting the single-leg STS test, all subjects performed a 10-minute warm-up protocol, including active and passive stretching exercises and STS movement. The subject started the test in a sitting position on a standard chair (height 45 cm, depth, 40 cm, width 40 cm; without back support and armrest) with the knee flexed at 90°. Then, the subject completed the test by standing up as quickly as possible and ending in a standing position with full knee extension (25). In the rising phase, it was ensured that the opposite leg did not touch the ground in any way and was kept in a comfortable position (44). Unlike the STS tests applied bilaterally, the subject was not expected to sit back on the chair after standing up because "one repetition" performed in accordance with the specified test procedure was accepted as valid by theforce plate software (Figure 1). If the relevant repetition was not performed in accordance with the test procedure due to various reasons (i.e., the lack of full knee extension, unused leg touching the ground), the software considered this repetition invalid, and the test was repeated. After each valid repetition, the subject moved off the force plate, and following a short rest period, the starting position was taken again on the unloaded plate (zero offset procedure), and the second and third repetitions were performed for the dominant and non-dominant legs, respectively. The average of the three repetitions (for each single-leg STS trial) was used for analysis. All repetitions were carried out with the hands-on hips.

INSERT FIGURE 1 HERE

The quantified parameters obtained from the MARS in the single-leg STS test included: STS time (s), which is the time in seconds required to voluntarily shift the center of gravity forward, beginning in the seated position and ending with full weight bearing on the feet; GRF (% body weight), which is the GRF exerted by the legs during the rising phase and expressed as a percentage of the subject's body weight; and CoP sway velocity (mm/s), which is the average CoP sway velocity over the base of support during the rising (30).

The representative diagrams of the single-leg STS test parameters (STS time, GRF, and CoP sway velocity) obtained from MARS are shown in Figure 2.

INSERT FIGURE 2 HERE

Single-leg counter-movement jump test

Before starting the single-leg CMJ test, all subjects performed a standardized warm-up protocol for approximately five minutes, including stretching and mobility exercises in which the major muscle groups of the lower limbs (adductor, hamstring, calf, quadriceps, and gluteus) were activated. After the warm-up, the main test phase was initiated following the trial repetitions. The subjects completed the single-leg CMJ test (dominant and non-dominant leg) by following the protocol specified by Meylan et al. (23). Briefly, the test started with the test leg fully extended on the center point of the force plate and the other leg at hip level with the knee joint at 90° flexion. Then, the subject was asked to jump as high as possible (flight) by coming to a self-selected depth (braking) that he determined suitable for the counter-movement. After jumping, the test was completed by landing on the platform with the tested leg (Figure 3). Subjects were not allowed to move or swing the opposite leg in any way during the jump phase (6), and this was vigilantly monitored by a member of the research team. The hands were positioned on hips during all phases of the test. A repetition that was not performed in accordance with the specified test procedure was considered invalid, and the repetition was repeated. The average of a total of three successful repetitions was used for the analysis. A recovery time of 30 seconds was given to prevent fatigue between repetitions.

INSERT FIGURE 3 HERE

Force plate-based vertical jump parameters, including jump height calculated from take-off velocity (m), mean power (W), mean force (N), and mean velocity (m/s), were used for analyses. These parameters were obtained from the MARS and have been commonly used in similar studies (21, 28).

Statistical analysis

Descriptive statistics (mean ± SD) were used to describe the data and normality was checked using Q-Q plots and histograms. The relative reliability of single-leg STS variables obtained from a piezoelectric force plate was determined using the intraclass correlation coefficient (ICC) and their 95% confidence intervals. We used the ICC (3, k) model based on multiple measurements, consistency, and two-way mixed effects (15, 36). Absolute reliability was examined with the standard error of measurement (SEM) and coefficient of variation (CV).

We explored systematic bias using a repeated measures analysis of variance (ANOVA) with generalized eta squared (η^2_G) from the ANOVA calculated as a measure of effect size and interpreted as: 0.01 (small), 0.06 (medium), and 0.14 (large), respectively (11). When the ANOVA was statistically significant (i.e., providing evidence of systematic bias), we employed linear trend analyses to further investigate the presence of learning effects. Reliability statistics (ICC, SEM, CV) were calculated using the SimplyAgree package (10) in R (R Foundation for Statistical Computing, Vienna, Austria). Additionally, the relationships between variables derived from single-leg STS and those derived from single-leg CMJ (jump height, mean force, velocity, and power) were tested through Spearman's rank correlation coefficient (ρ) due to non-normality. The size of ICC point estimates and Spearman's rank correlation coefficients was interpreted as: poor (< 0.5), moderate (0.50 to 0.74), good (0.75 to 0.89), and excellent (≥ 0.9) respectively, in line with guidelines (15). The level of statistical significance was set at $p < 0.05$.

RESULTS

Descriptive statistics for force plate measures of STS performance (dominant and non-dominant leg) during day 1, 2, and 3 are presented in Table 2.

INSERT TABLE 2 HERE

Intra-day reliability

In the dominant leg, CoP sway velocity obtained by the single-leg STS test showed excellent intra-day reliability (ICC = 0.90, CV = 8.7%), whilst measures of STS time and GRF demonstrated moderate intra-day reliability (ICC = 0.65 to 0.74, CV = 4.3 to 11.2%). In the non-dominant leg, all single-leg STS measures demonstrated good intra-day reliability (ICC = 0.79 to 0.86, CV = 3.8 to 9.8%). However, there was evidence of systematic bias for measures of STS time and GRF in the non-dominant leg, with trend analysis providing evidence of a learning effect for STS time (Table 3).

Inter-day reliability

STS time, GRF, and CoP sway velocity showed moderate inter-day reliability in the dominant leg (ICC = 0.54 to 0.74, CV = 5.8 to 13.5%) and good inter-day reliability in the non-dominant leg (ICC = 0.75 to 0.82, CV = 4.6 to 9.7%). STS time in the non-dominant leg, and CoP sway velocity in both legs, showed evidence of learning effects across days (Table 3).

INSERT TABLE 3 HERE

Relationship with single-leg CMJ performance (convergent validity)

STS time in the dominant and non-dominant legs was inversely related to single-leg CMJ mean velocity (ρ = -0.38 to -0.47; $p < 0.05$). CoP sway velocity in the non-dominant leg showed positive correlations with CMJ mean power and velocity (ρ = 0.38 to 0.54; $p < 0.05$), and CoP sway velocity in the dominant leg was positively correlated to CMJ mean force (ρ = 0.38; $p = 0.041$). No measure of single-leg STS was significantly related to the CMJ height ($p > 0.05$). A correlation matrix is presented in Table 4.

INSERT TABLE 4 HERE

DISCUSSION

Reliable measures of single-leg STS performance parameters are needed to quanitify lower-limb functional strength and identify potential asymmetries. This study is the first to examine the test-retest (intre-day and inter-day) reliability of single-leg STS performance parameters obtained on a force plate in trained adults. In accordance with our hypothesis, all measures obtained from the non-dominant leg in the single-leg STS test showed good intra-day and inter-day reliability, and measures taken from the dominant leg showed moderate to excellent reliability. The time taken to rise during the single-leg STS test (STS time) and CoP sway velocity were significantly correlated to single-leg CMJ variables in both legs, showing a high level of convergent validity.

In many sports, performance optimization is related to the asymmetry of lower limb strength and balance (34). The single-leg STS test has been used in clinics and research to assess lower limb muscle strength and knee function (1, 39). Reduced performance in single-leg STS test has been recently shown in anterior cruciate ligament injured persons either compared to a healthy group or the non-injured leg at three to nine months after surgery (24) and even as long as two decades after injury (38). Moreover, decreased single-leg STS performance has been shown to be predictive of knee osteoarthritis five years later (40). The high mechanical demands of the single-leg STS test could be more relevant for assessing reduced capabilities of lower limbs as well as strength imbalances between lower limbs rather than a bilateral form of this test (39).

Two previous recent studies have tested the reliability of the single-leg STS test in different study designs. Waldhelm et al. (44) examined the test-retest and inter-rater reliability of the time to complete five repetitions and the maximum repetitions performed in 30 seconds single-leg STS test in a sample of healthy college-aged individuals. Their results showed that both protocols had excellent inter-rater reliability (ICC > 0.97) and good to excellent test-retest reliability (ICC > 0.86). Thongchoomsin et al. (39) reported excellent test-retest reliability (ICC = 0.96) for the time to complete five repetitions single-leg STS test in 40 healthy young-middle-aged individuals. Our results from the single-leg STS test obtained via a force plate in trained adults are in line with these findings. Intra-day and inter-day reliability for time to rising (STS time) was moderate and good for dominant and non-dominant legs, respectively (Table 3). However, the results reported from our study, although reliable, showed lower ICC point estimates compared to the aforementioned literature which could be attributed to differences in the measurement procedure.

Even though the time to complete the STS test can be easily measured using a stop-watch, measurement errors from manual recordings are greater compared with more sophisticated technologies (41). Therefore, data derived from force plates could reflect more accurate test-retest reliability than manual assessment. Furthermore, the selection of the single-leg STS test could lead to a more variable motor pattern rather than a number of STS repetitions collected with a stop-watch. This hypothesis is partially supported by the results of Waldhelm et al. (44) who showed lower ICC values during five repetitions single-leg STS test (ICC = 0.87) compared to the maximum repetitions performed in 30 seconds single-leg STS test (ICC = 0.94). In our study, it was evident during the trend analysis (systematic bias) which revealed that some parameters such as STS time and CoP sway velocity showed a learning effect acrossdays of testing, despite that a familiarization procedure was carried out.

Our study not only examined the test-retest reliability of the STS time but also related parameters to single-leg STS performance derived from a force plate. The STS performance is usually expressed by the STS time, but in fact, it largely depends on postural control and quadriceps strength (20). Postural control is frequently assessed in sport science and rehabilitation setting as an outcome measure in athletic performance testing, risk of injury, and readiness to return to play (18). In our study, postural control during the single-leg STS test was assessed by CoP sway velocity, which refers to the sway velocity of the total force applied to the center of the supporting surface while rising from the chair, and is crucial during athletic performance tasks (27). A meta-analysis involving 346 individuals demonstrated that CoP sway velocity was largely deficient in anterior cruciate ligament injured athletes compared to healthy matched controls during single-leg assessment tests (18). Our results showed excellent (ICC = 0.90) and good (ICC = 0.83) intra-day reliability for CoP sway velocity for dominant and non-dominant leg, respectively, and similar inter-day reliability for both legs (ICC = 0.74 in the dominant leg and ICC = 0.75 in the non-dominant leg) (Table 3). Considering that postural control is an important condition for athletes (27), it can be expected that athletic performance may be associated with single-leg STS performance. Motor functions like postural stability and vertical jump are essential for athletic performance and even activities of daily living (7). The single-leg CMJ is a widely used vertical jump test for lower limb explosive power, which is involved in most sportive actions and it represents a stronger indicator of the capacity of each limb (28). In fact, the Spearman's correlation (convergent validity) findings of our study show that the STS time and CoP sway velocity during the single-leg STS test were significantly correlated to single-leg CMJ variables such as force, power, and velocity performed during the jump (Table 4). This result reveals that the single-leg STS performance is indicative of the explosive power and body stability of the lower limb.

Despite that the STS time during the STS test is the primary measure of function, other related parameters to GRF have been shown to be more related to physical performance than STS time (33). The amount of force exerted by the leg to the ground during the rising phase of the single-leg STS test was calculated as GRF in this study. In this context, the lower limb strength of athletes is very likely to affect the single-leg STS movement mechanics and performance. Our results showed moderate to good intra-day and inter-day reliability for GRF obtained by the dominant and non-dominant leg, respectively (Table 3). Interestingly, the dominant leg showed lower reliability values than the non-dominant leg for most single-leg STS parameters. These findings could be attributed to differences in GRF values between legs; the dominant leg showed lower strength outputs than the non-dominant leg (Table 2), which is ostensibly due to participants using their non-dominant leg more actively in the athletic tasks because the non-dominant leg may be preferable to the dominant leg in some athletic and sport-specific tasks (i.e., support body weight, shooting, passing) (3). This phenomenon has been previously reported in the literature; whereas almost all subjects choose to kick a ball with their self-reported dominant leg, during unilateral stabilizing tasks such as standing on one leg or jumping, around 50% of subjects switch to use their non-dominant leg (13, 42). Therefore, leg dominance could be partly dependent on the context of the task affecting subsequent performance and, therefore, the reliability of the measures.

There are some limitations to this study. Although the single-leg CMJ was used as a performance parameter in our study, different test options specific to the lower limb can be associated with the single-leg STS test performance. Furthermore, participants in this study were all non-injured males, and thus the results may not be generalizable to individuals who are in a rehabilitation program for a sports injury or female athletes, who may show different patterns of lower-limb strength asymmetry (2).

To conclude, the force plate-based single-leg STS test provides reliable measures of STS time, CoP sway velocity, and GRF in trained athletes, particularly when performed with the non-dominant leg. In addition, STS time and the CoP sway velocity were significantly correlated to single-leg CMJ variables in both legs, showing a high level of convergent validity. Therefore, our findings suggest the single-leg STS test can be used to characterise lower-limb functional strength and identify lower-limb assymetries in trained athletes.

PRACTICAL APPLICATION

The single-leg STS is a useful test tool in the trained athlete population because it provides an assessment of functional strength and lower-limb asymmetry. As a closed-kinetic chain activity, the single-leg STS test may be particularly beneficial in the context of rehabilitation after lower-limb injury, where functional lower-limb asymmetries are salient to return-to-play and when single-leg jumping may be contraindicated. Thus, the single-leg STS test may be preferred in this context to the unilateral CMJ, which is commonly used by practitioners to assess lower-limb performance. Our results suggest that force plate data generated during the single-leg STS test is highly reliable and closely related to single-leg CMJ performance. Therefore, the single-leg STS test can provide important information on functional lower-limb asymmetry in trained athletes. Owing to the consistently good test-retest reliability, practitioners may prefer to use the non-dominant leg to characterise single-leg functional strength.

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FIGURE CAPTIONS

Figure 1. Single-leg sit-to-stand test on a force plate

Figure 2. Representative single-leg sit-to-stand data obtained from the Kistler Measurement, Analysis and Reporting Software.

Figure 3. Single-leg counter-movement jump on a force plate

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Table 1. Baseline characteristics of study participants (mean ± SD)

Parameters	**N=30**
Age (years)	21.37 ± 1.65
Body mass (kg)	66.3 ± 6.8
Height (m)	1.77 ± 0.05
Body mass index ($kg \cdot m^{-2}$)	21.17 ± 2.11
Dominant leg counter-movement jump	
Jump height (m)	0.15 ± 0.07
Mean power (W)	850 ± 206
Mean force (F)	885 ± 244
Mean velocity (m/s)	0.97 ± 0.15
Non-dominant leg counter-movement jump	
Jump height (m)	0.16 ± 0.06
Mean power (W)	840 ± 208
Mean force (F)	888 ± 232
Mean velocity (m/s)	0.98 ± 0.17

Table 2. Descriptive statistics of piezoelectric force plate measures of single-leg sit-to-stand performance (mean ± SD)

Single-leg sit-to-stand parameters	**Day 1[a]**	**Day 2**	**Day 3**
Dominant leg			
Sit-to-stand time (s)	1.95 ± 0.35	1.91 ± 0.33	1.89 ± 0.34
Ground reaction force (%BW)	75.3 ± 5.4	74.3 ± 5.3	72.6 ± 8.2
CoP sway velocity (mm/s)	240 ± 46.8	224 ± 39.0	212 ± 44.8
Non-dominant leg			
Sit-to-stand time (s)	1.98 ± 0.36	1.92 ± 0.27	1.80 ± 0.27
Ground reaction force (%BW)	76.3 ± 6.1	74.7 ± 7.5	74.5 ± 5.8
CoP sway velocity (mm/s)	249 ± 34.5	219 ± 38.2	222 ± 38.0

[a]Descriptive statistics for day 1 are taken from the first session (day 1- trial1); BW = body weight; CoP (center of pressure).

Table 3. Intra-day and inter-day reliability of dominant and non-dominant leg sit-to-stand parameters

Single-leg sit-to-stand parameters	**Reliability**			**Systematic bias**	
	ICC (95% CI)	**SEM**	**CV%**	**ANOVA (p, η^2_G)**	**Trend analysis (p, β)**
INTRA-DAY RELIABILITY					
Dominant leg					
Sit-to-stand time (s)	0.65 (0.42-0.80)	0.24	11.2	0.08 (0.039)[a]	-
Ground reaction force (%BW)	0.74 (0.57-0.85)	3.8	4.3	0.58 (0.006)[a]	-
CoP sway velocity (mm/s)	0.90 (0.83-0.94)	24.7	8.7	0.30 (0.007)[a]	-
Non-dominant leg					
Sit-to-stand time (s)	0.79 (0.65-0.88)	0.21	9.6	0.005* (0.056)	0.025* (-0.13)
Ground reaction force (%BW)	0.86 (0.76-0.92)	3.5	3.8	0.35 (0.008)	-
CoP sway velocity (mm/s)	0.83 (0.72-0.90)	28.4	9.8	0.033* (0.030)	0.13 (-12.8)
INTER-DAY RELIABILITY					
Dominant leg					
Sit-to-stand time (s)	0.54 (0.23-0.74)	0.29	13.5	0.64 (0.006)[a]	-
Ground reaction force (%BW)	0.67 (0.46-0.81)	4.9	5.8	0.12 (0.029)	-
CoP sway velocity (mm/s)	0.74 (0.56-0.85)	31.3	11.9	0.004* (0.068)	0.014* (-20.0)
Non-dominant leg					
Sit-to-stand time (s)	0.75 (0.59-0.86)	0.21	9.7	0.014* (0.055)[a]	0.028* (-0.12)
Ground reaction force (%BW)	0.82 (0.70-0.90)	4.1	4.6	0.18 (0.016)	-
CoP sway velocity (mm/s)	0.75 (0.58-0.86)	26.1	9.7	<0.001* (0.125)	0.005* (-19.6)

[a]Sphericity correction applied. *Statistically significant ($p<0.05$)

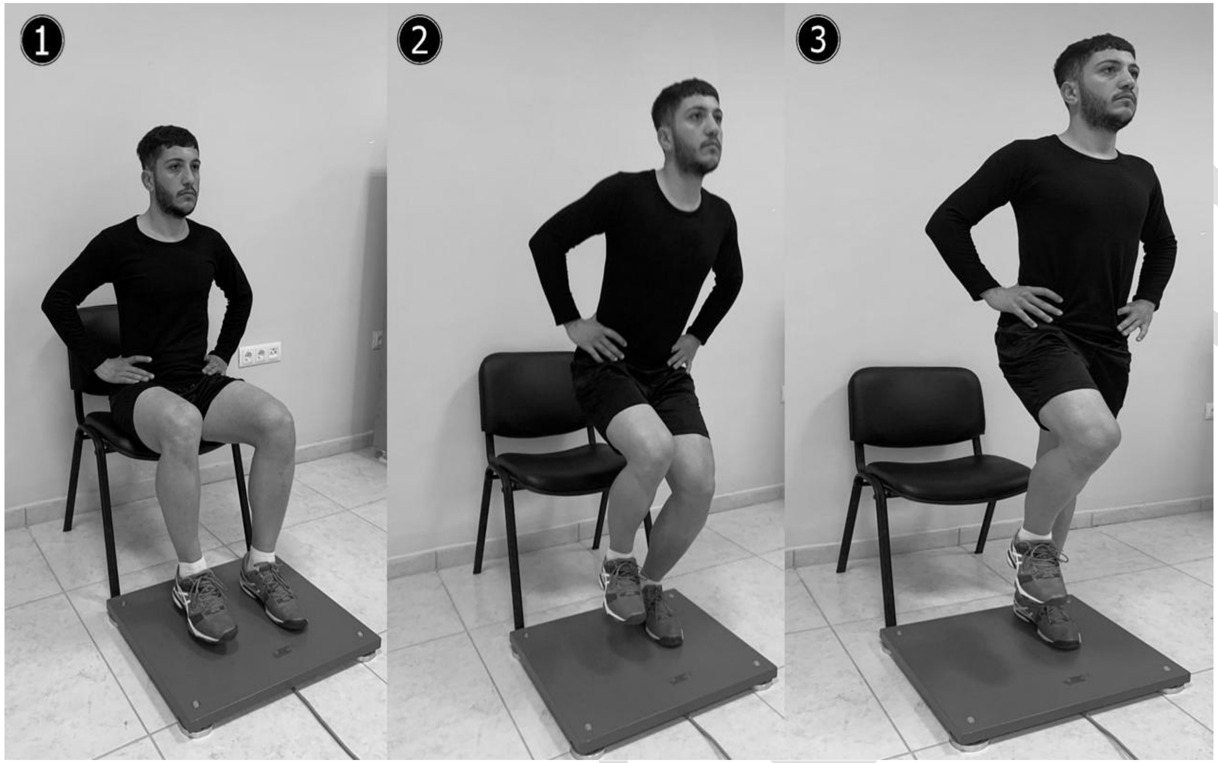
ANOVA = analysis of variance; CI = confidence interval; CV = coefficient of variation; ICC= intraclass correlation coefficient; η^2_G*; generalised eta-squared;* SEM = standard error of measurement; BW = body weight; CoP (center of pressure).

Table 4. Correlations between single-leg-sit-to-stand and single-leg counter-movement jump parameters

Single-leg sit-to-stand parameters	**Single-leg counter-movement jump parameters**							
	Jump Height (m)		**Mean power (W)**		**Mean force (N)**		**Mean velocity (m/s)**	
Dominant leg	ρ	***p***	ρ	***p***	ρ	***p***	ρ	***p***
Sit-to-stand time (s)	-0.18	0.33	-0.18	0.35	-0.02	0.90	**-0.47**	**0.009***
Ground reaction force (%BW)	-0.15	0.42	-0.07	0.70	-0.30	0.11	0.12	0.52
CoP sway velocity (mm/s)	0.05	0.81	-0.26	0.17	**-0.38**	**0.041***	-0.01	0.97
Non-dominant leg								
Sit-to-stand time (s)	-0.20	0.29	-0.20	0.30	0.07	0.73	**-0.38**	**0.038***
Ground reaction force (%BW)	-0.28	0.13	-0.02	0.93	-0.04	0.83	0.12	0.52
CoP sway velocity (mm/s)	0.24	0.21	**0.38**	**0.042***	-0.09	0.63	**0.54**	**0.002***

*Statistically significant (p<0.05)

ρ = Spearman's rank correlation coefficient; BW = body weight; CoP (center of pressure).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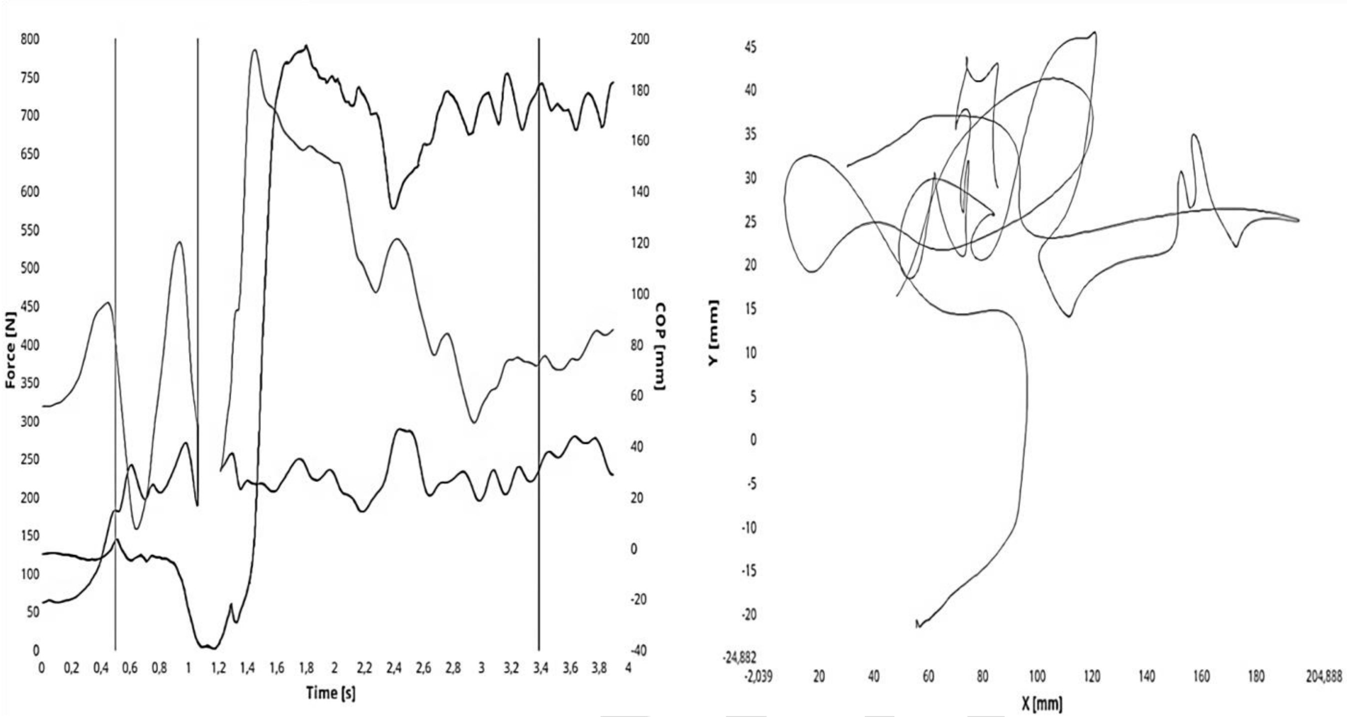
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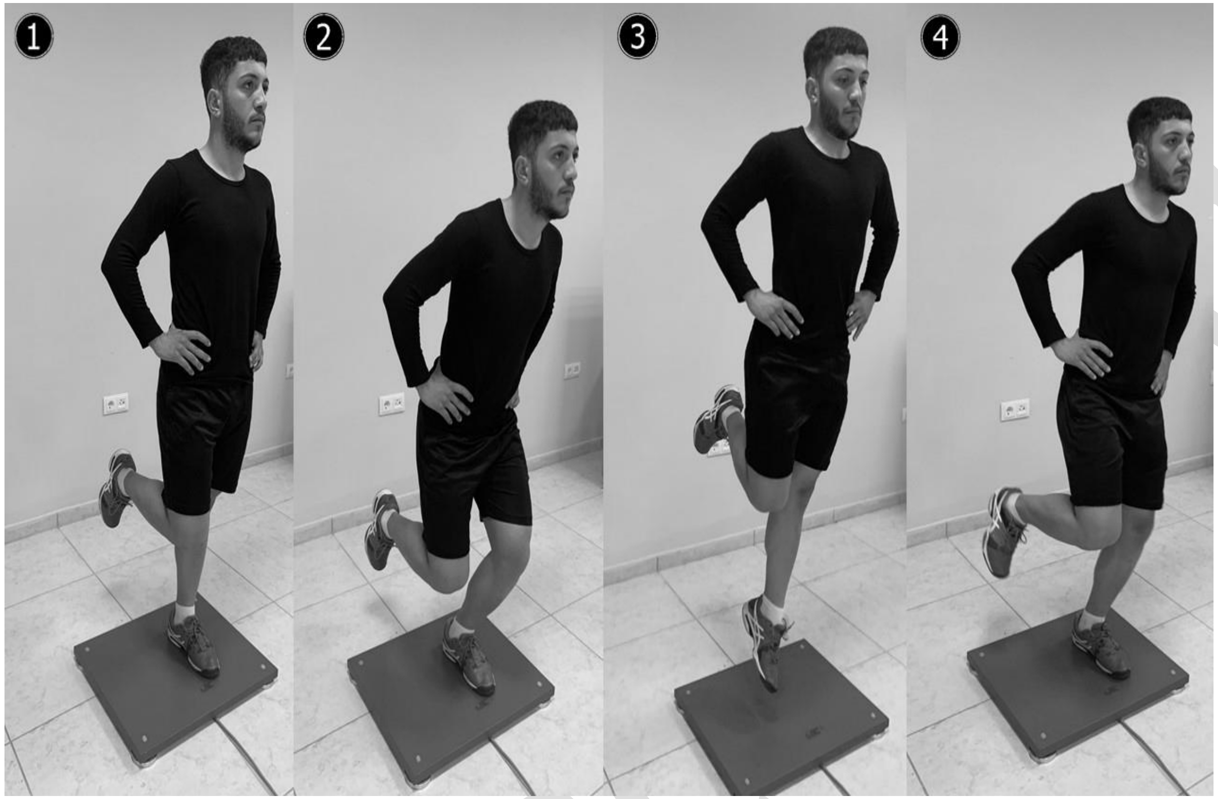
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