CLINIMETRIC PROPERTIES OF THE ONE LEG SIT TO STAND TEST IN EXAMINING UNILATERAL LOWER LIMB MUSCLE STRENGTH AMONG YOUNG ADULTS

Abstract

Background: One-leg sit to stand (one-leg STS) test is a new clinical test developed to measure the unilateral lower limb (LE) muscle strength among young adults. This study examined the test-retest reliability and the criterion-concurrent validity of the one-leg STS.

Methods: Forty young adults (mean age ± SD, 28.07 ± 5.39 years) participated in the study. The one-leg STS test was administered in two separate assessment sessions to examine test-retest reliability. Two-leg sit to stand (two-leg STS) test was administered and the performance time was measured. The concentric peak strength of hip flexors/extensors, knee flexors/extensors, and ankle dorsi-flexors/plantar-flexors were determined using an isokinetic dynamometer. An intraclass correlation coefficient (ICC) was used to examine the test-retest reliability of one-leg STS. The criterion validity of the one-leg STS was evaluated against the performance of the two-leg STS using an independent sample T-test. The concurrent validity of the one-leg STS was evaluated by investigating the relationships between STS performance time and LE muscle strength using Pearson correlation coefficients.

Results: The reliability analysis showed that one-leg STS performance time had excellent test-retest reliability ($ICC_{3,1} = 0.960$, $p < 0.001$). Also, the one-leg STS performance time was not different between the first and second sessions, $t(39) = 0.672$, $p = 0.506$. The performance time of the one-leg STS test was significantly greater than the two-leg STS test ($t(39) = 20.63$, $p < 0.001$). The performance time of the one-leg STS significantly correlated with the concentric peak strength of all LE muscles ($p < 0.05$).

Conclusions: The one-leg STS test demonstrated excellent reliability and criterion-concurrent validity against the two-leg STS and the LE muscle strength. The one-leg STS test was simple to administer and could be beneficial for the assessment of unilateral LE muscle strength of young adults in clinical settings.

Keywords: sit-to-stand test, muscle strength, measurement, reliability, validity, Young adults

What's already known about this topic?

- Two-leg sit to stand is an established clinical test to measure lower limb muscle strength among the elderly population
- Two-leg sit to stand test may be too easy for younger adults to perform as it requires very less muscular effort
- Two-leg sit to stand test may not give direct quantification of unilateral lower limb muscle strength among young adults

What does this article add?

- One-leg sit to stand test is a new clinical test developed to be applied among young adults
- One-leg sit to stand test has reported good reliability and concurrent-criterion validity
- One-leg sit to stand test is an appropriate test to measure unilateral lower limb muscle strength among young adults

1. Introduction

Reduction in muscle strength can occur in young adults due to any muscular injuries during the sporting activities and as a result of muscle disuse following any surgical procedures (1-3). In such an instance, a clinical test to assess muscle strength is essential to determine the effects of the treatment and to monitor the progress of the rehabilitation program. Isokinetic dynamometry device such as the Biodex system is considered as a reliable and valid tool for the assessment of concentric torque of lower extremity (LE) that represents muscle strength and function (4,5). However, its relatively high cost, manpower training and time consuming long procedures have hindered its application in clinical practice. As the majority of the rehabilitation settings could not afford to have and use an isokinetic device in day to day practice, there is a strong need to develop a simple, alternate and effective clinical test to examine the LE muscle strength as part of the rehabilitation process.

A performance-based functional test is considered an alternative clinical method for the assessment of muscular strength due to its simplicity to administer and it provides additional information related to physical performance (6). While some functional tests such as Berg Balance Test and Single-leg Stance test are used to measure balance, other clinical tests namely unilateral squat test and two-leg sit-to-stand (STS) test are used to measure the strength of LE muscles (7-11). However, there are some limitations to the application of these tests in young adults. A unilateral squat test requires a piece of specific equipment such as adjusted-weight barbells to determine the amount of leg strength (9). The strength evaluation of LE muscles using a two-leg STS may not be a true reflection of strength from each leg equally, as asymmetrical LE joint moments between right and left legs was reported during a two-leg STS task (12, 13) Also, young healthy adults have relatively higher maximal voluntary contraction than older adults and utilize less of their strength capability during a traditional two-leg STS performance (13). A more specific and challenging functional test to measure LE muscle strength in young adults would be clinically useful. Therefore in the current study, a single-leg STS was developed as an alternate new clinical test to determine the LE muscle strength among young adults.

Although various clinical tests such as Berg balance test, single leg stance test and unilateral squat test are currently in practice, the one-leg STS developed in this study is different from the rest of the tests. For example, Berg balance test and single leg stance test are used to assess balance where an individual works on a single leg to maintain their balance during the test (7, 11). On the other hand, the one-leg STS test evaluates the LE muscle strength where an individual performs a sit to stand activity on a single leg using their own body weight. Also, the one-leg STS is different from the unilateral squat test, as the latter test is performed in a squat position using external load (barbell) to determine lower limb strength (1-Repetition maximum strength (8, 9, 11). In the above context, the one-leg STS is a new clinical test which needs to be investigated further in terms of biomechanical and clinimetric properties.

During the one-leg STS test, one might argue that the LE muscles require more strength capacity to perform the test because the source of active muscles work is reduced from two legs to one leg but the body weight still the same. From a biomechanical standpoint, using one leg to perform a sit-to-stand task should place higher mechanical demand on LE muscles eventually producing a high-performance time than a traditional two-leg STS test. Thus, the comparison of the performance time of the one-leg STS test against the two-leg STS would indicate the criterion validity of the one-leg STS. Also, it was hypothesized that the performance time of a one-leg STS test would be associated with LE muscle strength and hence, the validity of the one-leg STS could be established by examining the relationship between its performance time and the LE muscle strength as measured by the isokinetic dynamometry. For any clinical test to be used in clinical practice, the clinimetric properties such as reliability and validity need to be established (14, 15). As the one-leg STS is a new clinical test, it is pertinent to establish the validity and reliability of the test before it can be used in clinical practice. Thus, the main aim of this study was to investigate the test-retest reliability and the criterion-concurrent validity of the one-leg STS in examining LE muscle strength among healthy young adults.

2. Methods

2.1 Participants

A convenience sample of 40 young healthy participants (20 men and 20 women) participated in the study. All the participants were recruited through a study recruitment poster advertised within the university and the local community. Any male or female aged between 20-40 years who had not taken any medication over the past six months were included in the study. Any participants who had a history of musculoskeletal or neurological conditions that might affect the muscle strength were excluded from the assessment. The study protocol was approved by the ethical committee of an institutional review board with ethical approval number MUICRB,COA-2016/180.2810. All participants were informed about the study procedures and gave written informed consent prior to participating in the study.

2.2 Procedures

The study was conducted according to the Guidelines for Reporting Reliability and Agreement Studies (GRRAS) guidelines (15). All the participants completed two testing sessions on separate days within a 3-day period. The first session contained three procedures namely measurement of anthropometric characteristics (body weight, height, and leg length), measurement of the 1st session of the one-leg STS test and the two-leg STS. During the second session, the 2nd trial of the one-leg STS test and an isokinetic strength measurement of the LE muscles were measured. The participants performed the one-leg and two-leg STS in the random order. The one-leg STS test and the isokinetic strength test were performed on the participant's dominant leg determined by a leg dominance test (16). All the measurements were collected by a qualified therapist.

2.3 One-leg sit-to-stand test

The one-leg STS test was performed with bare feet kept stable on the ground. A height-adjustable chair without armrest and backrest was used. The seat height was adjusted to the knee joint level. Participants were instructed to sit over the chair with bare feet placed slightly behind the knee joint and both arms folded across their chest. The participants were instructed to sit on the chair with their non-test leg (non-dominant leg) lifted just above the floor throughout the test as shown in Figure 1. After two practice trials, participants performed the test as fast and safely as possible for two trials with a three-minute rest between the trials. Participants were asked to rise from a chair five times. Timing began when the examiner said "Go" and stopped when the participant sat on the chair on the fifth repetition. During the test, the one-leg STS movement was checked visually, making sure that participant stood with hip and knee fully extended and sat with buttock made firm contact with the seat in each repetition. The faster of the two trials was used for data analysis, as the faster trial would represent the maximum effort of the LE muscles being tested (17). Each participant repeated the second trial (retest) of the one-leg STS test within three days period under the same testing protocol.

2.4 Two-leg sit to stand test:

After a five-minute rest, the two-leg STS test was administered in the same testing environment using an established protocol (11). The only difference in the test was that the participant used two legs instead of the one-leg to perform the sit to stand task on the chair. The illustration of the two-leg sit to stand test was shown in Figure 2. Each participant repeated the tests for five-time and the fastest of the two trials was taken for data analysis.

2.5 Measurement of LE muscle strength

Measurement of LE muscle strength (hip flexors/extensors, knee flexors/extensors, and ankle plantar-flexors/dorsi-flexors) was measured through an established protocol (18). The measurement was performed in random order using an isokinetic dynamometer (System 4, Biodex Medical Systems Inc., NY, USA) at an angular velocity of 60 degrees/second. Participants were positioned based on the manufacturer guidelines for strength testing of the hip, knee, and ankle joints. Participants performed submaximal contractions to warm up the muscles and to familiarize them with the test. For the actual test, participants performed three maximal concentric contractions of each joint for two trials with a five-minute rest between trials. Torque data were normalized to body weight. A trial with the highest average concentric peak strength was used for data analysis.

2.6 Statistical analysis

A mean correlation between LE muscle strength and STS time from a previous study (8) was used to estimate the sample size and hence, a sample size of 40 participants was considered appropriate for the study. Paired sample t-test was used to compare the performance time between the first and second sessions of the one-leg STS test and as well as to compare the performance time between the two-leg STS test and the one-leg STS test (1st session). An intra class correlation coefficient ($ICC_{3,1}$) was used to examine the test-retest reliability of the one-leg STS time. As the data were normally distributed, Pearson correlation coefficients were used to examine the relationship between the peak torque of the LE muscle strength and the performance time of the one-leg STS test. Significance level was set at $p < 0.05$ for all analyses.

3. Results

The demographic characteristics of the participants are presented in Table 1. The mean performance time of both the single-leg STS tests and the two-leg STS together with the mean concentric peak torque to body weight ratio of the LE muscles (hip flexors/extensor, knee flexors/extensors, and ankle dorsi-flexors/plantar-flexors) are reported in Table 2. The one-leg STS time was not different between the 1st session (11.87 ± 1.46 sec) and the 2nd session (11.83 ± 1.38 sec), $t(39) = 0.672$, $p = 0.506$. Also, the performance time of the one-leg STS test (1st session; 11.83 ± 1.38 second) was significantly greater than that of the two-leg STS test (7.55 ± 0.73 sec), $t(39) = 20.63$, $p < 0.001$. The test-retest reliability of the one-leg STS time was found to be excellent ($ICC_{3,1} = 0.960$, 95%, CI = 0.925 - 0.979, $p < 0.001$).

Pearson correlations between the mean concentric peak torque to body weight ratio of the LE muscle strength (hip flexors/extensor, knee flexors/extensors, and ankle dorsi-flexors/plantar flexors) and the performance time of the one-leg STS are presented in Table 3. All LE muscles concentric peak strength had significant negative moderate to high correlation with the one-leg STS performance time ($p < 0.01$). However, the performance time of the two-leg STS test was not associated with LE muscle strength, except the ankle dorsi-flexors.

4. Discussion

As one-leg STS is a newly developed clinical test, the current study was mainly carried out to determine the reliability and validity of the test. The study findings supported that one-leg STS test holds high reliability and validity to examine the functional strength of the LE muscles. Also, the study reported on the performance time of the one-leg STS among healthy young adults which was recorded as 11.87 ± 1.46 secs and 11.83 ± 1.38 secs in both the first and second trials respectively. In clinical practice, one-leg STS test is applicable for both acute and chronic LE injuries. Evidence suggests an average of 12 days for LE muscle strain to return back to play and other functional activities (19). Therefore, the test could be used within two weeks of injury for LE muscle strength assessment before return to play and as well as to monitor changes in the LE muscle strength in chronic injuries. For any new clinical outcome measures and clinical tests, it is crucial to establish normative reference values as it helps clinicians to improve the precision and responsiveness of the clinical test (20). Therefore, future study should be carried out to establish the normative reference values of one-leg STS test as it might assist the clinicians to apply the test effectively in clinical practice.

The one-leg STS performance time in young adults was found to be highly reliable due to standardized testing protocols. Firstly, the study methodology for the reliability analysis was carried out as per the protocol recommended Guidelines for Reporting Reliability and Agreement Studies (GRRAS) guidelines (15). Secondly, the factors that might influence sit-to-stand performance including the chair seat height and starting position were controlled in this study (21). A height-adjustable chair was used in this study to account for different leg lengths as it was reported that rising from relatively lower seat height requiring more leg extensor moment and affecting STS times (21). The non-test leg position was controlled such that it was lifted steadily above the floor throughout the test to prevent leg momentum that might assist the STS movement. In other words, the clinical protocol for the one-leg STS used in the current study might inform clinicians and sports practitioners to perform the test with greater accuracy in the rehabilitation settings.

In the current study, the two-leg STS test was used as one of the comparable gold standards to establish the criterion validity of the one-leg STS. The findings of the test established clear criterion validity for the one-leg STS as it showed that a significantly longer performance time was required to perform the test with one leg (11.8±1.4 secs) when compared to the two-leg STS test (7.5±0.7 secs). When compared to the past studies on the performance time of the two-leg STS (8.1±1.7 secs), the one-leg STS performance time (11.8±1.4 secs) obtained in the current study among young adults was longer (22, 23). To perform an STS task with one leg, the participants needed to lift most of the bodyweight up and down with greater effort; consequently, a significant extended performance time occurred.

Past evidence suggests that LE extremity muscle strength had been used as a comparable gold standard to establish the validity of the two-leg STS test (10). Previous studies investigating two-leg STS performance in adults aged over 60 found that knee extensor muscles generate large knee moments during the transfer and the extension phases when standing up from the chair as well as during descending to a chair (24, 25). Therefore in the current study, LE muscle strength as measured by the isokinetic dynamometry Biodex system was used as one of the other comparable gold standards to establish the concurrent validity of the one-leg STS. When compared to isometric contraction, concentric torque is better suited to represent muscle strength during a dynamic task such as a one-leg STS movement, hence the concentric torque was measured as an indicator of LE muscle strength (5). The findings showed that the strength of the LE muscles was negatively correlated with the performance time of the one-leg STS test. In other words, for the one-leg STS test, the strength capacity of the LE muscles is crucial for the success of the task because the source of active muscle work is reduced from two legs to one leg while the body weight is the same. However, the ankle dorsi-flexors was the only muscle group associated with the two-leg STS performance time which might suggest that less muscular effort was required as the STS task was performed by two legs. The study participants were instructed to keep the feet stable on the ground during the test and hence, it was not clear whether foot position had any effects on the one-leg STS performance time. Perhaps, future biomechanical studies are necessary to investigate the effects of foot position on the one-leg STS test.

The current study has some limitations. Firstly, we examined only the hip, knee, and ankle muscles. Other postural muscle groups such as trunk muscles and hip adductors might also influence the one-leg STS movement. Secondly, kinetic parameters such as joint moments and power could also provide more explanation regarding the kinetic demands during performing the one-leg STS test. Thus, future studies should consider adding electromyography on trunk and hip abductor muscles to assess any differences in muscle activity between the two-leg STS and one-leg STS test. Also, kinetic variables during the one-leg STS test should be examined by incorporating a force plate measurements. Thirdly, the external validity of the study findings are limited only to the younger population and hence, the one-leg STS needs to be investigated further in different populations and pathological conditions before it could be effectively used in the clinical practice. The body mass ratio and muscular fatigue are some of the other variables which can influence the sit to stand task (26, 27). Further research is warranted to understand the influence of limb dominance on the one-leg STS test and hence, clinicians may need to interpret the test findings with caution when comparing the test between dominant and non-dominant leg. Moreover, other clinimetric properties namely minimal clinically important difference (MCID) needs to be developed further, as clinicians may use it to make a decision on how much score of the one-leg STS test is considered as a minimal important change or clinically useful. Nevertheless, the current study provided a clear protocol for the one-leg STS and suggested preliminary data about the performance time of one-leg STS for the clinicians to use the one-leg test in the rehabilitation practice to measure the functional strength of the LE muscles in the absence of expensive isokinetic dynamometry equipment.

5. Conclusions

The one-leg STS test was found to be highly reliable and valid to examine the functional strength of the LE muscles in the younger population against the two-leg STS task and isokinetic dynamometer. The one-leg STS test is simple to administer and could be beneficial for the assessment of unilateral lower extremity muscle strength of young adults in clinical settings.

Declarations

Ethics approval and consent to participate

The study was approved by the ethical committee of the University Institutional Review Board. All participants of this study gave their written informed consent to participate in this study.

Consent for publication

Not applicable.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Campbell EL, Seynnes OR, Bottinelli R, et al. Skeletal muscle adaptations to physical inactivity and subsequent retraining in young men. Biogerontology. 2013; 14(3):247-59.
2. Greenhaff PL. The molecular physiology of human limb immobilization and rehabilitation. Exerc Sport Sci Rev. 2006; 34(4):159-63.
3. Järvinen TA, Järvinen TL, Kääriäinen M, Kalimo H, Järvinen M. Muscle injuries: biology and treatment. Am J Sports Med. 2005; 33(5):745-64.
4. Stark B, Emanuelsson P, Gunnarsson U, Strigård K. Validation of Biodex system 4 for measuring the strength of muscles in patients with rectus diastasis. J Plast Surg Hand Surg. 2012; 46(2):102-5.

5. Zawadzki J, Bober T, Siemieński A. Validity analysis of the Biodex System 3 dynamometer under static and isokinetic conditions. Acta Bioeng Biomech. 2010; 12(4):25-32.
6. Kollock R, Van Lunen BL, Ringleb SI, Oñate JA. Measures of functional performance and their association with hip and thigh strength. J Athl Train. 2015; 50(1):14-22.
7. Eli C, Shmuel B, Meir L, Joav M, Raymond C, Five Clinical Tests to Assess Balance Following Ball Exercises and Treadmill Training in Adult Persons With Intellectual Disability. J. Gerontol. 2003; 58(8):M767–772.
8. Poulsen DR, James CR. Concurrent validity and reliability of clinical evaluation of the single leg squat. Physiother Theory Pract. 2011; 27(8):586-94.
9. McCurdy K, Langford G. Comparison of unilateral squat strength between the dominant and non-dominant leg in men and women. J Sports Sci Med. 2005; 4(2):153-9.
10. McCarthy EK, Horvat MA, Holtsberg PA, Wisenbaker JM. Repeated chair stands as a measure of lower limb strength in sexagenarian women. J Gerontol A Biol Sci Med Sci. 2004; 59(11):1207-12.
11. Clark MS. The Unilateral Forefoot Balance Test: Reliability and validity for measuring balance in late midlife women. NZ j. physiother. 2007; 35(3): 110-118
12. Lundin TM, Grabiner MD, Jahnigen DW. On the assumption of bilateral lower extremity joint moment symmetry during the sit-to-stand task. J Biomech. 1995; 28(1):109-12.
13. Wheeler J, Woodward C, Ucovich RL, Perry J, Walker JM. Rising from a chair. Influence of age and chair design. Phys Ther. 1985; 65(1):22-6.
14. Fava, GA., Tomba, E. and Sonino, N. Clinimetrics: the science of clinical measurements. Int. J. Clin. Pract. 2012; 66 (1): 11-15.

15. Kottner J, Audigé L, Brorson S, et al. Guidelines for Reporting Reliability and Agreement Studies (GRRAS) were proposed. J Clin Epidemiol. 2011; 64(1):96-106.
16. Velotta J, Weyer J, Ramirez A, Winstead J, Bahamonde R. Relationship between leg dominance tests and type of task. Portugese J Sport Sci. 2011; 11:1035-8.
17. Takai Y, Ohta M, Akagi R, Kanehisa H, Kawakami Y, Fukunaga T. Sit-to-stand test to evaluate knee extensor muscle size and strength in the elderly: a novel approach. J Physiol Anthropol. 2009;28(3):123-8.
18. Biodex System 4 Pro Operation Manual, Shirley, NY. https://www.biodex.com/sites/default/files/850000man_08262revb.pdf. Accessed on 13th April, 2020.
19. Hallen A, Ekstrand J. Return to play following muscle injuries in professional footballers. J Sports Sci. 2014;32(13):1229–1236
20. McKay MJ, Baldwin JN, Ferreira P, et al. Normative reference values for strength and flexibility of 1,000 children and adults. Neurology. 2017; 88(1):36–43.
21. Janssen WG, Bussmann HB, Stam HJ. Determinants of the sit-to-stand movement: a review. Phys Ther. 2002; 82(9):866-79.
22. Butler AA, Menant JC, Tiedemann AC, Lord SR. Age and gender differences in seven tests of functional mobility. J Neuroeng Rehabil. 2009; 6:31.
23. Whitney SL, Wrisley DM, Marchetti GF, et al. Clinical measurement of sit-to-stand performance in people with balance disorders: validity of data for the Five-Times-Sit-to-Stand Test. Phys Ther. 2005; 85(10):1034-45.
24. Goulart FR, Valls-Sole J. Patterned electromyographic activity in the sit-to-stand movement. Clin Neurophysiol. 1999; 110(9):1634-40.

25. Cheynel N, Mourey F, Peschaud F, et al. Standing-up/sitting-down movement. Electromyographic analysis of 4 muscles of lower limb and the erector spinae muscle: study of anticipatory postural adjustments. Morphologie. 2002; 86(274):23-6.
26. Savelberg HH, Fastenau A, Willems PJ, Meijer K. The load/capacity ratio affects the sit-to-stand movement strategy. Clin Biomech (Bristol, Avon). 2007; 22(7):805-12.
27. Roldán-Jiménez C, Bennett P, Cuesta-Vargas AI. Muscular Activity and Fatigue in Lower-Limb and Trunk Muscles during Different Sit-To-Stand Tests. PLoS ONE 2015; 10(10): e0141675.

Table 1 Demographic characteristics of the participants

Variables	**Mean ± SD**	**Range**
Age (yr)	28.07 ± 5.39	21-39
Weight (kg)	61.91 ± 13.40	42.10 - 95.00
Height (m)	1.66 ± 0.79	1.50 - 1.81
Leg length (m)	0.85 ± 0.04	0.76 - 0.94
Number of dominant leg (right/left)	35/5	

Table 2 Performance time of both the one-leg and two-leg STS tests and concentric peak torque of the LE muscle strength

Variables	Mean ± SD	Range
One-leg STS time (sec)		
1st session	11.87 ± 1.46	8.78 - 15.20
2nd session	11.83 ± 1.38	9.19 - 15.00
Two-leg STS time (sec)	7.55 ± 0.73	6.09 - 9.65
Concentric peak torque (Nm/kg)		
Hip flexors	1.21 ± 0.36	0.56 - 2.01
Hip extensors	2.47 ±0.83	0.83 - 3.87
Knee flexors	1.02 ± 0.31	0.47 - 1.82
Knee extensors	1.72 ± 0.56	0.79 - 3.02
Ankle dorsi-flexors	0.43 ± 0.12	0.25 - 0.69
Ankle plantar-flexors	1.10 ± 0.21	0.78 - 1.45

Table 3 Pearson correlations (r) between LE muscle strength, and the performance time of the one-leg and the two-leg STS tests

Independent variables	**One-leg STS performance time**	**Two-leg STS performance time**
	r (p-value)	**r (p-value)**
Body weight	0.256 (0.111)	0.126 (0.437)
Height	-0.169 (0.298)	-0.197 (0.224)
Concentric peak torque		
Hip flexors	-0.495 (0.001)	-0.110 (0.498)
Hip extensors	-0.702 (< 0.001)	-0.167 (0.304)
Knee flexors	-0.535 (< 0.001)	-0.236 (0.142)
Knee extensors	-0.711 (< 0.001)	-0.190 (0.241)
Ankle dorsiflexors	-0.571 (< 0.001)	-0.397 (0.011)
Ankle plantarflexors	-0.425 (0.006)	-0.222 (0.168)

Figure 1 Illustration of the sit-to-stand testing conditions a) one-leg sit-to-stand test

Figure 2 Illustration of the sit-to-stand testing conditions b) Two-leg sit-to-stand test