

Original Research

The Single-Leg Wall Squat Test: An Assessment of Functional Lower Extremity Endurance in University Students

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BACKGROUND

The single-leg wall squat (SLWS) has the potential to be used as a functional test to assess lower extremity muscular endurance. While previous research has explored its muscular activation patterns, its relationship with isolated muscle strength and potential sex-specific responses remains under-investigated.

PURPOSE

This study aimed to examine the descriptive statistics of the SLWS and the correlation between handheld dynamometry (HHD) measures of hip and knee strength and SLWS test performance. Secondary aims included the investigation of potential sex differences in SLWS test performance and associated physiological responses.

STUDY DESIGN

Observational cohort

METHODS

Thirty healthy university students (13 female, 17 male) aged 18-30 years participated. Maximal isometric strength of the dominant leg's hip extensors, abductors, and knee extensors was measured using HHD. Participants then performed a SLWS test on the dominant leg to volitional failure, with repetitions counted and perceived exertion (RPE) assessed. Heart rate was monitored and reasons for test termination were recorded. Descriptive statistics were calculated for all measures. Pearson correlations assessed relationships between isometric strength and single-leg wall squat repetitions, while independent samples t-tests compared measures between sexes.

RESULTS

Average SLWS test performance was 76.2 ± 35.2 repetitions. Average heart rate and RPE post-SLWS were 146.3 ± 17.1 bpm and 8.3 ± 1.2 out of 10, respectively. SLWS test performance was not significantly correlated with HHD measures. No significant sex differences were observed in SLWS performance, although they were observed for HHD measures and RPE. Gluteus maximus fatigue was the most commonly reported reason for test termination (41.4%).

CONCLUSION

The SLWS test demonstrated potential as a functional endurance assessment, eliciting moderate-to-high physiological strain. However, performance did not correlate with isolated muscle strength, suggesting the test captures a complex interplay of factors

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beyond isolated muscle function. No sex differences were observed in SLWS performance. Further research is needed to explore the test's validity and sensitivity to changes in lower extremity function.

LEVEL OF EVIDENCE

3

INTRODUCTION

The single-leg wall squat (SLWS) is a valuable tool for assessing lower extremity muscular endurance, a key factor in athletic performance, injury prevention, and maintaining functional independence.¹ As a closed-kinetic chain exercise, it effectively replicates the demands placed on the lower extremities during functional activities by engaging multiple muscle groups simultaneously in a weight-bearing position.² Previous research using electromyography (EMG) has confirmed that the SLWS strongly activates key lower extremity muscles, including the quadriceps, gluteus maximus, and adductors.³⁻⁵

While the SLWS effectively activates these muscle groups, the relationship between isolated muscle strength and performance on this task remains unclear. Handheld dynamometry (HHD) provides a quantitative measure of peak force production, but it may not fully capture the complex neuromuscular coordination and endurance demands inherent in the SLWS. The SLWS requires sustained muscle activation and postural stability, factors that may not be fully reflected in HHD measurements.

Furthermore, potential sex differences in SLWS performance warrant investigation. While females often exhibit lower absolute strength compared to males,⁶ it is unknown whether these differences translate into disparities in muscular endurance tasks like the SLWS. Females may demonstrate greater endurance capacity or utilize different muscle activation strategies, potentially influencing their performance. Understanding potential sex-specific responses is crucial for developing appropriate assessment and training protocols for diverse populations.

This study aimed to address these gaps by establishing descriptive statistics for SLWS performance in university students, providing baseline data for future research. The correlation between HHD measures of hip and knee strength and SLWS performance was also investigated to determine how isolated strength contributes to endurance in a functional task. Finally, potential sex differences in SLWS performance, HHD measures, and physiological responses (heart rate, rate of perceived exertion [RPE]) were explored to reveal any sex-specific variations in muscular endurance, strength, and physiological responses to the SLWS.

A moderate positive correlation was hypothesized to exist between HHD measures and the number of SLWS repetitions completed, suggesting that greater isolated strength would contribute to improved endurance. Additionally, it was hypothesized that males would outperform females on the SLWS due to their typically greater muscle mass and strength. This investigation will provide valuable insights into the factors influencing SLWS performance and inform

the development of effective training and rehabilitation programs.

METHODS

Thirty healthy university students (13 female, 17 male) aged 18–30 years volunteered to participate in this study. Exclusion criteria included any history of lower extremity surgery, neurological disorders, or cardiovascular conditions. Participants were instructed to refrain from strenuous exercise for 24 hours before testing and to wear comfortable athletic attire. The study was approved by the university's institutional review board, and all participants provided written informed consent.

Height was measured to the nearest 0.5 cm using a wall-mounted stadiometer. Body mass was measured to the nearest 0.5 kg using a calibrated digital scale.

Maximal isometric strength of the hip extensors (gluteus maximus), hip abductors (gluteus medius), and knee extensors (quadriceps) was assessed using a handheld dynamometer (FEI Lafayette Manual Muscle Tester). Standardized testing procedures were followed as per the manufacturer's instructions. Participants performed two repetitions of each muscle group tested. Mean absolute values of strength were used to analyze the correlation between SLWS repetitions and strength values, while mean strength values relative to body weight were used when analyzing differences between males and females. Handheld dynamometry for these muscle groups has demonstrated high reliability in previous studies.^{7,8} To minimize the potential for tester bias, one researcher conducted all HHD assessments while another conducted the SLWS test in a separate room.

The SLWS test was performed by all participants following at least two minutes of rest after HHD assessments. Participants were instructed to stand with their back, shoulders, and head against a wall, feet together and 30 centimeters (12 inches) away from the wall as determined by a measuring tape. One leg was lifted off the ground by extending the knee of the limb not being tested. Participants were then instructed to slowly lower their body by flexing the knee and hip of the stance leg being tested until their fingertips touched a tape placed 15 cm (six inches) below the starting position of their fingertips. Participants were then instructed to return to the starting position.

Repetitions were performed at a speed of two seconds per repetition (one second down, one second up, as paced by a metronome), and counted until volitional failure. Volitional failure was defined as the inability to complete a full repetition with correct form in time with the metronome. Standardized verbal feedback to maintain appropriate speed and form was provided throughout the test.

Resting heart rate was measured after five initial minutes of seated rest. Heart rate was also recorded immediately after the SLWS test. Perceived exertion was assessed immediately after the SLWS test using the Modified Borg CR10 RPE scale (0-10).⁹ Participants verbally reported the primary reason for stopping the SLWS test, with options including fatigue in specific muscle groups (gluteus maximus, quadriceps, hamstrings), knee pain, balance issues, or other.

Descriptive statistics (mean $\pm$ standard deviation) were calculated for participant characteristics, handheld dynamometry (HHD) measures, single-leg wall squat (SLWS) performance, and physiological responses. Pearson correlation coefficients were calculated to assess the relationship between HHD strength measures and SLWS repetitions, with low correlation defined as <0.29 , moderate as $0.3-0.49$, and high as $0.5-1$. Independent samples t-tests were used to compare SLWS performance, HHD measures, and physiological responses between male and female participants. All statistical analyses were performed using IBM SPSS Statistics v23.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at $p < 0.05$.

RESULTS

The results of the independent t-tests and descriptive statistics for participant characteristics, HHD measures, SLWS performance, and physiological and fatigue responses are presented in [Table 1](#). The SLWS test demonstrated low to moderate correlations with hip extension ($r=0.32$, $p=0.08$), hip abduction ($r=0.28$, $p=0.14$), and knee extension ($r=0.38$, $p=0.04$) strength. Although the correlation with knee extension strength was the only measurement that reached statistical significance, the magnitude was still relatively low.

No significant differences were found between males and females in SLWS performance ($p=0.0953$). Although there were differences in the mean number of completed SLWS repetitions between males and females (85.9, SD = 30.4 for males, 63.5, SD = 38.1 for females), this difference was not statistically significant. The most frequently reported primary reason for test termination was gluteus maximus fatigue (41.4%) followed by quadriceps fatigue (34.5%), and hamstring fatigue (3.5%). No participants reported terminating the test due to pain, loss of balance, or reasons other than muscle fatigue.

DISCUSSION

This study revealed weak to moderate correlations between handheld dynamometer (HHD) measures of hip and knee strength and single-leg wall squat (SLWS) performance. This finding reinforces the growing understanding that functional tasks like the SLWS involve complex interactions between multiple muscle groups and neuromuscular systems, going beyond isolated muscle strength.^{10,11} The SLWS challenges not only the force-generating capacity of individual muscles but also the coordination, balance, and proprioceptive feedback essential for single-leg stability.¹²

An unexpected finding was the absence of significant sex differences in SLWS performance, given the documented disparities in muscle mass and strength between males and females.⁶ These results suggest that these strength differences may not translate into significant disparities in muscular endurance tasks like the SLWS. This could be attributed to the SLWS primarily recruiting Type I muscle fibers, which are relatively resistant to fatigue and exhibit less sexual dimorphism compared to Type II fibers.^{13,14} Additionally, females may compensate for lower absolute strength by employing different movement strategies or activating muscles in a more coordinated manner.¹⁵ Further research incorporating EMG and kinematic analysis could elucidate these potential mechanisms and provide a deeper understanding of how different sexes perform the SLWS. As the SLWS task requires supporting and moving one's own body mass, absolute strength values rather than those normalized to body weight were retained as the primary measure for this functional, weight-bearing endurance test. Analyzing normalized strength could be a focus for future research, especially in populations with greater body mass heterogeneity.

In addition to performance, the high average rate of perceived exertion (RPE) reported by participants underscores the demanding nature of the SLWS test and its ability to elicit substantial fatigue in the lower extremities. The predominance of gluteus maximus fatigue as the primary reason for test termination aligns with previous EMG findings emphasizing the significant activation of this muscle group during the SLWS.³⁻⁵ This highlights the importance of gluteal muscle endurance in maintaining proper form and sustaining performance in this exercise and other activities that involve single-leg stance and dynamic movements.¹⁶

While the SLWS test demonstrates promise as a valid and reliable measure of lower extremity muscular endurance, it is essential to acknowledge its limitations. The homogeneous sample of university students in this study may not be representative of the general population. Future research should include participants with varying ages, activity levels, and health conditions to enhance the generalizability of the findings and explore the clinical implications of different SLWS performance levels across populations. Additionally, the potential for fatigue effects between HHD and SLWS testing cannot be completely ruled out. Future studies could incorporate a randomized, counterbalanced design or a longer rest period between tests to mitigate this issue.

This study provides preliminary normative data for the SLWS test in university students. However, future research should expand the normative database to include diverse populations and investigate the test's sensitivity to change following interventions such as strength training or rehabilitation programs. Further exploration of the neuromuscular and physiological mechanisms underlying SLWS performance may also shed light on its relationship with other measures of lower extremity function and inform targeted interventions.

Table 1. Descriptive statistics for study measures

Variable	Total (n=30)	Females (n=13)	Males (n=17)	p-value
Age (years)	21.7 ± 2.7	21.3 ± 2.5	22.1 ± 2.8	NA
Height (cm)	171.1 ± 11.9	162.2 ± 10.5	179.9 ± 5.4	NA
Weight (kg)	73.3 ± 16.0	64.8 ± 14.2	81.8 ± 12.7	NA
Hip Extension HHD (kg)	25.9 ± 11.2	15.8 ± 5.4	33.6 ± 7.7	0.0003*
Hip Abduction HHD (kg)	32.9 ± 10.9	22.9 ± 5.0	40.6 ± 7.3	0.0014*
Knee Extension HHD (kg)	32.8 ± 14.2	20.9 ± 6.5	41.9 ± 11.4	0.0003*
SLWS Repetitions	76.2 ± 35.2	63.5 ± 38.1	85.9 ± 30.4	0.0953
HR Post-SLWS (bpm)	146.3 ± 17.1	149.5 ± 18.9	143.9 ± 18.9	0.3985
RPE Post-SLWS (0-10)	8.3 ± 1.2	7.6 ± 0.9	8.7 ± 1.1	0.0092*
Primary Reason for SLWS Termination	Gluteus Maximus Fatigue (41.4%)	Quadriceps Fatigue (50.0%)	Gluteus Maximus Fatigue (47.1%)	NA

* = significant difference between males and females at the $p < 0.05$ level; bpm = beats per minute; cm = centimeters; HHD = handheld dynamometry; kg = kilograms

CONCLUSION

The SLWS test demonstrated low, mostly non-significant correlations with lower body strength. There were no notable sex differences in SLWS performance, although significant strength differences between groups existed. Participants primarily ended the test due to gluteus maximus and quadriceps fatigue. The low to moderate correlations observed between SLWS performance and HHD measures suggest the SLWS test may offer a unique assessment of integrated lower limb function that extends beyond isolated muscle strength. Furthermore, the absence of significant sex differences in SLWS performance suggests that it may allow comparisons regardless of sex, making it a suitable assessment tool for both males and females.

The potential applications of the SLWS in athletic training, rehabilitation, and injury prevention warrant further investigation. For instance, the SLWS could be used to track progress in athletes recovering from lower limb injuries or

to identify individuals at risk of falls due to poor lower extremity endurance. By providing a comprehensive assessment of functional lower limb capacity, the SLWS has the potential to enhance clinicians' understanding of movement and contribute to improved outcomes in various populations.

CONFLICT OF INTEREST

There are no potential conflicts of interests, including financial arrangements, organizational affiliations, or other relationships that may constitute a conflict of interest regarding the submitted work.

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