

**UNIVERSIDADE FEDERAL DE CIÊNCIAS DA SAÚDE DE
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**O Single Leg Bridge Test avalia a
capacidade de resistência dos
músculos flexores do joelho?**

Universidade Federal de Ciências da Saúde
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Trabalho de Conclusão de Curso de
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Dedico este trabalho aos meus amados pais, sem os quais a conclusão desta etapa da minha vida não seria possível. Embora possam não encontrar sentido nos textos aqui apresentados, vocês compreendem como ninguém o verdadeiro significado por trás desta conquista. Agradeço por todo o apoio, amor e dedicação que tornaram este momento possível. Vocês são a base sólida que sustentou cada passo desta jornada.

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RESUMO

Objetivo: O principal objetivo foi investigar a correlação entre a pontuação no Teste de Ponte em Uma Perna (SLBT) e a capacidade de resistência dos músculos flexores do joelho, conforme mensurado. Secundariamente, nosso objetivo foi investigar a correlação do índice de simetria dos membros (LSI) encontrado no SLBT e no teste de resistência dos flexores do joelho.

Delineamento: Estudo transversal.

Local: Laboratório universitário.

Participantes: Quarenta homens saudáveis e fisicamente ativos.

Principais desfechos: Correlação entre as pontuações no SLBT e a capacidade de resistência dos flexores do joelho, avaliada por meio de um protocolo isocinético composto por 30 contrações máximas concêntricas dos flexores do joelho a 120°/s.

Resultados: A pontuação no SLBT (27±7 repetições) não apresentou correlação significativa com a capacidade de resistência dos flexores do joelho fornecida pelo pico de torque isocinético (52±9%) ou trabalho (57±9%). Da mesma forma, o LSI encontrado no SLBT (99±12%) não apresentou correlação significativa com os valores de LSI encontrados no teste de resistência dos flexores do joelho (107±26% e 102±18%).

Conclusão: O SLBT não avalia a capacidade de resistência dos músculos flexores do joelho.

Palavras-chave: Isquiotibiais, fadiga, força, validade.

ABSTRACT

Objective: The primary aim was to investigate the correlation between the Single Leg Bridge Test (SLBT) score and the endurance capacity of the knee flexor muscles as measured. Secondly, we aimed at investigating the correlation of limb symmetry index (LSI) found in the SLBT and the knee flexor endurance test.

Design: Cross-sectional study.

Setting: University laboratory.

Participants: Forty healthy and physically active men.

Main outcome measures: Correlation between SLBT scores and knee flexor endurance capacity assessed through an isokinetic protocol comprising 30 maximal concentric knee flexion contractions at 120°/s.

Results: The SLBT score (27 ± 7 reps) presented no significant correlation with knee flexor endurance capacity provided by isokinetic peak torque ($52 \pm 9\%$) or work ($57 \pm 9\%$). Similarly, LSI found in the SLBT ($99 \pm 12\%$) was not significantly correlated with LSI values found in the knee flexor endurance test ($107 \pm 26\%$ and $102 \pm 18\%$).

Conclusions: The SLBT does not assess the endurance capacity of knee flexor muscles.

Keywords: Hamstring, fatigue, strength, validity.

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LISTA DE ABREVIATURAS E SIGLAS

HSI - Hamstring strain injury;

HHD - Handheld dynamometer;

SLBT - Single Leg Bridge Test;

LSI - Limb symmetry index;

SD - Standard deviation;

CI - Confidence intervals.

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ARTIGO

Does the Single Leg Bridge Test evaluate the endurance capacity of the knee flexor muscles?

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INTRODUCTION

The hamstring strain injury (HSI) is a major concern in high-speed running-based sports. In football (soccer), for instance, a review including thirteen studies and 3868 players with 2 million sport exposure hours demonstrated that HSI accounted from 4% to 13% of all injuries (6). Despite the advances on injury prevention by the scientific community over the last few decades, elite European football clubs have been unsuccessful in significantly reducing the incidence of HSI (9). This results in significant setbacks for both the teams' performance and the financial health of the clubs (12). It is also noteworthy that around one in each five injured players experience a HSI recurrency, with more than two-thirds of these instances occurring within the initial two months of returning to sport (9). This underscores the importance of refining processes within the injury rehabilitation program, including the implementation of robust return-to-play criteria.

Poor muscle strength has historically been considered a potential risk factor for HIS (29). Prospective cohort studies conducted in various sports have yielded inconsistent results (15), possibly because they correlate injuries occurring over the course of a season with the muscular strength achieved in a single moment during the pre-season (2). Despite the uncertainties provided by scientific literature, chief medical officers of elite football clubs recognize muscle strength-related deficits as playing a pivotal role in HIS (10), and knee flexor strength assessments have been widely used to screen athletes potentially more susceptible to injury (4, 25). These assessments have also been esteemed in the context of HSI rehabilitation, with the latest clinical practice guide recommending their utilization in decision-making regarding the patients' progression (22). In addition, strength tests are the most common return-to-play criteria

adopted following a HSI in elite football (7, 32). Therefore, assessments of knee flexor strength have become a routine practice for prevention and rehabilitation of HSI.

The knee flexor muscle strength has been assessed through isokinetic dynamometers or specialized devices (e.g., Nordic hamstring exercise test), as well as isometrically using handheld dynamometers (HHD) and load cells. However, the expense associated with such apparatus is a hindrance for professionals dealing with athletes at potential risk or in rehabilitation following an HSI. The Single Leg Bridge Test (SLBT) emerged as a portable and cost-effective option for assessing the hamstring function in both the clinical setting and the field of play. Briefly, this test involves performing a unilateral bridge exercise with the tested leg supported on a 60cm-high platform until the task failure (more details in the Methods section). The SLBT has demonstrated reliability (intratester ICC = 0.77–0.89; intertester ICC = 0.89–0.91) (16) and gained prominence following Freckleton et al. (13) found that Australian footballers who experienced HSI during the season exhibited lower preseason SLBT scores. From there, studies have used the SLBT to assess the hamstring function in healthy subjects (20, 21, 30), as well as to help clinicians in decision-making on the athletes' rehabilitation progress and return to sport following HSI (19, 24).

It is noteworthy that recent evidence does not support the SLBT as a reliable tool for assessing the maximum strength capacity of the knee flexor muscles (14, 31). Gasparin et al. (14) did not find a significant correlation between the SLBT score and the knee flexor concentric or eccentric peak torque values. Similarly, the findings of Robaina et al. (31) revealed weak or nonexistent correlations between the SLBT score and maximum isometric strength values measured in the clinical setting through HHD-based tests. Taken together, the evidence suggests that the SLBT should not be used as a substitute for maximum knee flexor strength tests. Conversely, some authors suggest the SLBT as a test of 'hamstring endurance' (13, 21). It seems plausible that muscular endurance (i.e., the ability to resist fatigue) is the dominant factor due to the

nature of repetitions to failure in the SLBT. However, the relationship between the SLBT score and the knee flexor muscle endurance is still unknown. Therefore, the primary objective of the present study was to examine the correlation between the SLBT score and the endurance capacity of the knee flexor muscles in healthy individuals. Secondly, this study aimed to examine the correlation between limb symmetry index (LSI) provided by the SLBT and the and the knee flexor endurance test.

METHODS

Study Design

In this cross-sectional study, the volunteers attended the laboratory on two separate occasions with at least a 48-hour interval between them. During each visit, participants carried out either the SLBT or the knee flexor endurance test on the isokinetic dynamometer. The sequence of assessments was randomized. A single evaluator conducted all SLBT sessions while another conducted all isokinetic test sessions. Evaluators were blinded to the results of the test conducted by their colleague. This study was approved by the Federal University of Health Sciences of Porto Alegre (Porto Alegre, Brazil) ethics committee (#5.589.245) and all volunteers provided informed consent before starting study participation.

Participants

Volunteers were recruited through advertisements on social networks linked to the university community. To be included in this study, the volunteers had to attend the following criteria: male subjects, aged between 18 and 35 years and physically active (e.g., practitioner of individual sports, team sports or resistance training). Volunteers with history of knee or hip surgery, musculoskeletal injuries in the lower limbs in the 3 months prior to data collection (including hamstring strain injury), or any health conditions that generate contraindications to the performance of maximal strength tests

and/or muscular endurance tests (e.g., heart failure, arterial hypertension, and physical disability of the lower limbs) were excluded.

Procedures

Participants were informed to avoid vigorous training sessions 24 hours prior to assessments and the use of analgesics and/or anti-inflammatory drugs 48 hours before the procedures, in order to prevent interference in the results. They were also instructed not to consume stimulant substances (e.g., caffeine) on testing days. Data collection sessions started with a standardized warm-up protocol (5 minutes exercise on cycle ergometer with a cadence of 60 to 80 rpm and a self-selected load corresponding to a moderate intensity activity). During warm-up time, instructions were given about the tests to be performed and all the participants' doubts were clarified. Following the assessment of the first limb, a 5-minute pause was provided before conducting the test on the second limb. The assessment of the second limb was conducted only once the participant had affirmed complete recuperation from the preceding tests and indicated their readiness to exert a fresh maximal effort.

Single Leg Bridge Test

The SLBT (Figure 1-A) was conducted in accordance with the guidelines outlined by Freckleton *et al.* (13). After following the previously outlined warm-up routine and receiving clear instructions regarding the test procedure, participants were instructed to lie down on the ground, placing the heel of the limb being tested on a 60cm high box. Employing a goniometer, the limb being tested was set to an approximate 20° knee flexion angle. Participants were directed to fold their arms across their chest and use their heel to exert downward pressure, lifting their pelvis off the ground until their hip reached a fully extended position at 0°. An initial practice

repetition was performed to demonstrate the proper execution to the participants and to establish the target height for the upward movement. This elevation was measured using a one-meter scale to ensure consistency during the evaluation of the opposite limb. For a repetition to be considered valid, participants needed to touch their buttocks to the ground with each repetition without pause. Subsequently, they were required to make contact between their non-tested knee and the rater's hand, positioned at the predetermined target height, before returning to the starting position. Additionally, the non-working limb had to remain stable in a vertical position to prevent any momentum gained from swinging. If the correct form was compromised, a warning was issued, and the test was terminated at the next instance of faulty technique. Participants were encouraged to perform the SLBT and complete as many repetitions as possible until reaching failure.

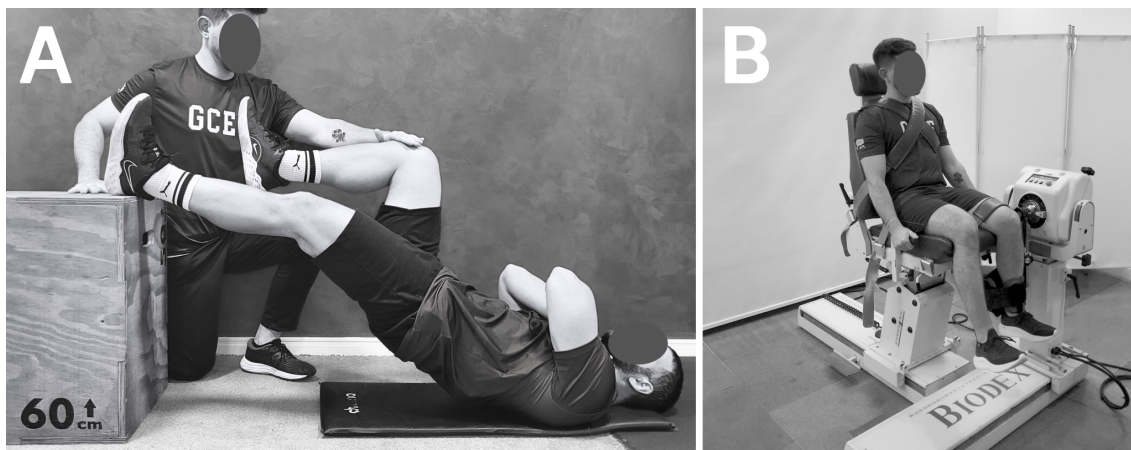


Figure 1: Illustration of the Single Leg Bridge Test (panel A) and positioning adopted in the knee flexor muscle endurance protocol at the isokinetic dynamometer (panel B).

Knee flexor endurance test

The endurance capacity of the knee flexor muscles was evaluated using an isokinetic dynamometer (Biodex System 4; Biodex Medical System, Shirley, NY). After following the previously outlined warm-up routine and receiving clear instructions

regarding the test procedure, participants were positioned appropriately on the isokinetic dynamometer in accordance with the manufacturer's guidelines for evaluating knee flexion movements (Figure 1-B). To acclimate to the equipment and prepare for the assessment, they executed 10 submaximal concentric knee flexion and extension repetitions at a speed of 120°/s. After a one-minute rest interval, participants initiated the knee flexor endurance test, which consisted of 30 maximal concentric knee flexion contractions (1). These contractions were performed at an angular velocity of 120°/s and encompassed a range of motion spanning 90°. Throughout the test, participants were encouraged to exert the highest level of intensity possible from the first repetition to the conclusion.

Outcomes

The “SLBT score” was documented as the number of valid repetitions executed in each limb during the SLBT execution. The endurance of the knee flexor muscles was assessed through two variables provided by the isokinetic dynamometer: peak torque and work. The “peak torque fatigue index” was determined as the percentage reduction in peak torque along the knee flexor endurance test. It was calculated by dividing the mean peak torque value obtained from the final 5 repetitions by the mean peak torque value from the initial 5 repetitions. The “work fatigue index” was calculated as the percentage decline in work along the knee flexor endurance test. It involved dividing the work executed during the last one third of the endurance test (last 10 repetitions) by the work performed during the first one third (first 10 repetitions) of the test. For both SLBT and knee flexor endurance test, the “limb symmetry index” (LSI) was calculated using the following equation: (left limb value / right limb value) x 100.

Statistical Analysis

Descriptive statistics was used to describe the participants' performance through mean, standard deviation (SD), 95% confidence intervals (CI), and minimum

and maximum values. The Shapiro-Wilk normality test was used to analyze the distribution. Correlations between SBLT scores and isokinetic fatigue indexes were assessed through Pearson's and Spearman's correlation coefficients for normal and non-normal data, respectively. A similar statistical approach was used to assess correlation between the LSI found in the SLBT and the knee flexor endurance test. The following correlation criteria were adopted: 0.69 or less, poor correlation; 0.70 to 0.79, fair correlation; 0.80 to 0.89, good correlation; and 0.90 to 1.0, excellent correlation (5). Statistical significance was set at 5% ($p < 0.05$) for the comparisons.

RESULTS

Forty healthy and physically active men (i.e., 80 limbs) were assessed in this study (25 ± 2 years old, 83 ± 8 kg, 176 ± 1 cm). Fifteen participants were recreational athletes of a range of sports: running ($n=6$), soccer ($n=2$), CrossFit ($n=1$), volleyball ($n=1$), basketball ($n=3$), Olympic weightlifting ($n=1$) and Sport Climbing ($n=1$). Some of these recreational athletes routinely practiced more than one sport. The other 25 volunteers were only resistance training practitioners.

There was no significant correlation between the SLBT score and the knee flexor fatigue indexes provided by peak torque or work ($p > 0.05$ for both, Table 1). Similarly, the LSI found in the LSBT was not significantly correlated with LSI found in the knee flexor endurance test ($p > 0.05$; Table 2). Scatter plots on Figure 2 further demonstrate the failed association between the SLBT scores and the endurance capacity of knee flexor muscles.

Table 1. Performance in the single leg bridge test and in the knee flexor endurance test ($n=80$ limbs).

	Mean (SD)	95% CI	Min; Max	Correlations with SLBT	
				<i>r or rho</i>	p-value

SLBT (reps)	27.23 (7.35)	25.59 to 28.87	10; 44	-	-
PT fatigue index (%)	51.75 (9.45)	49.65 to 53.85	24.30; 67.14	-0.038	0.737
Work fatigue index (%)	56.56 (8.51)	54.67 to 58.45	34.60; 70.40	0.078	0.489

Max, maximum; Min, minimum; PT, peak torque; SLBT, single leg bridge test.

Table 2. Limb symmetry index in the single leg bridge test and the knee flexor endurance test (n=40 volunteers).

	Mean (SD)	95% CI	Min; Max	Correlations with SLBT	
				<i>r</i> or <i>rho</i>	p-value
SLBT LSI (%)	98.79 (12.00)	94.95 to 102.63	73.33; 121.43	-	-
PT fatigue LSI (%)	107.53 (26.42)	99.08 to 115.98	66.06; 203.17	-0.100	0.540
Work fatigue LSI (%)	102.01 (17.80)	96.32 to 107.70	73.95; 170.23	0.031	0.849

LSI, limb symmetry index; Max, maximum; Min, minimum; PT, peak torque; SLBT, single leg bridge test.

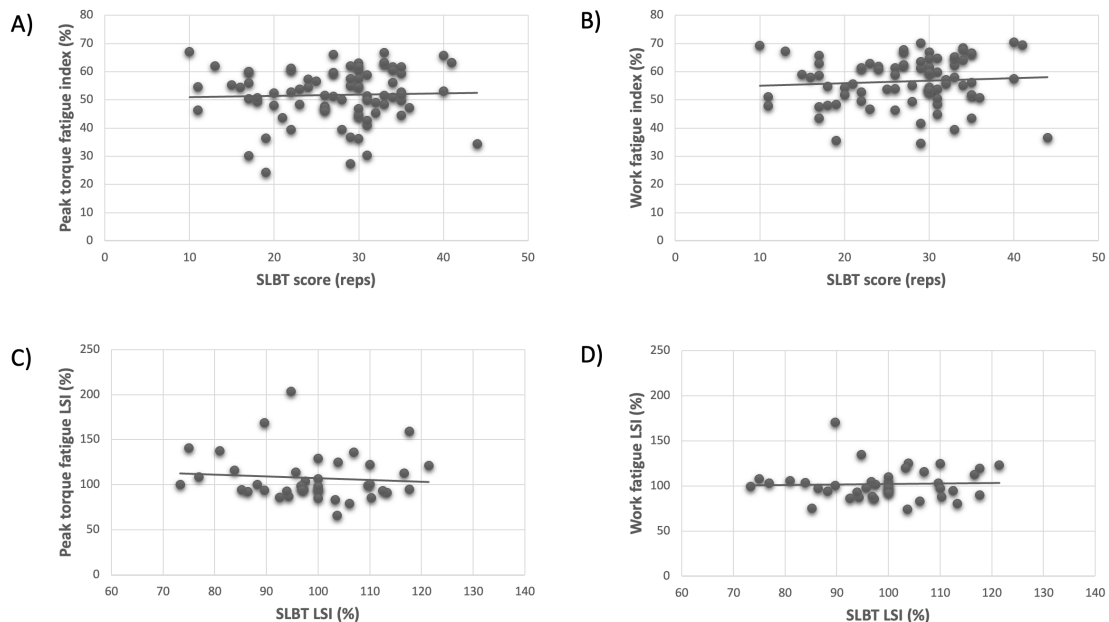


Figure 2. Scatter plots illustrating the relationship between the single leg bridge test (SLBT) and the knee flexor endurance test. Panels A and B present the testing performance (n=80 limbs). Panels C and D present the limb symmetry index (LSI; n=40 volunteers).

DISCUSSION

This study aimed to investigate the correlation between SLBT scores and knee flexor muscles endurance capacity. The results demonstrated that there was no significant correlation between SLBT score and the knee flexor fatigue index provided by peak torque or work measurements. Additionally, the between-limb performance symmetry in SLBT score, assessed through LSI, did not show a significant correlation with those found in the isokinetic endurance test.

The SLBT was unable to measure knee flexor isokinetic peak torque (14) or isometric maximum strength (31). There was no correlation even when the isometric strength test was performed in the same position as the SLBT (31). Considering the nature of repetitions until task failure proposed by the SLBT, our initial hypothesis was that this test would present a good correlation with the endurance capacity of the knee flexor muscles. Hence, we opted for the gold standard tool to assess muscular strength-related variables and implemented a testing protocol under highly controlled conditions in a laboratory environment to evaluate knee flexor muscle endurance. To broaden the scope of our analysis, we employed torque and work as methods for measuring muscle endurance. In both instances, our protocol proved effective in inducing muscle fatigue, as indicated by average values of approximately 52% and

59% drop in torque and work over the course of the 30 maximum-intensity repetitions, respectively.

The results of the present study contradict the initial hypothesis that the SLBT score would be associated with the knee flexor muscle endurance. It is reasonable to speculate some factors that may have played a role in these results. Firstly, it should not be ignored that fatigue is a phenomenon with a task-dependent nature (3). Hence, a protocol involving a predetermined number of maximum-intensity isokinetic contractions can elicit a different fatigue response compared to a protocol continuing until task failure in a fixed resistance exercise (in the case of SLBT, using the volunteers' body mass). The volunteers were acquainted with the tasks involved in the SLBT and the isokinetic endurance test, but they did not have the opportunity to undergo multiple assessments to refine their execution strategy for each test. The instructions and verbal stimuli were provided to stimulate volunteers to exert maximum effort to attain the greatest number of repetitions in the SLBT and perform each contraction with the highest possible intensity since the beginning of the isokinetic endurance test. Nevertheless, the perception of discomfort and fatigue triggered by each test is individual-specific, influencing the volunteer's responses during the execution of each test.

Concurrently, and possibly with a greater relevance on results, the contribution of gluteal muscles to the hip extension movement during the SLBT should be highlighted. Gluteus maximus is considered the most relevant hip extensor (23, 28). Specifically during unilateral bridge exercises, studies have found similar activation levels between gluteus maximus and hamstrings (11) or higher activation for gluteus maximus compared to hamstrings (34). In addition, the middle segment of gluteus medius and the posterior segment of gluteus minimus also exhibit high activation during the unilateral bridge (26). Therefore, gluteal muscles probably played a key role on the SLBT score, while have no participation on the volunteers' performance in the

isokinetic endurance tests. In addition to the gluteal muscles, bridge exercises involve stabilizing muscles in the lumbopelvic region, such as lumbar multifidus and longissimus thoracis (11). Interestingly, erector spinae muscles exhibit relative activation levels similar to those observed in the knee flexors during some bridge exercises (17, 18). Hence, status of these trunk muscles may also influence the SLBT score.

Sprinting appears to be the task that imposes the greatest demands on the hamstring muscles (33), and this muscle group plays a crucial role in horizontal force production during sprint actions (27). Interestingly, in a situation of repeated sprint-induced fatigue, the gluteal muscle seems to assume a relatively more significant role than the hamstrings in horizontal force production (8). It has been hypothesized that primary hip extensors, such as the gluteus maximus, may compensate for potentially altered hamstring muscle function due to fatigue in a synergistic manner during sprinting (8). Applying this hypothetical scenario to the SLBT, the fatigue of the gluteal muscles would likely have a more decisive impact on the number of single-leg bridge repetitions before task failure than the hamstrings themselves. This reinforces the notion that our results might have varied if the isokinetic endurance test had incorporated repetitive hip extension movements instead of knee flexion.

It is reasonable to speculate that the SLBT is, therefore, a test assessing the endurance of the hip extensors as a whole. If this is accurate, the SLBT score should not be solely attributed to the condition of the hamstrings or glutes in isolation. From a practical standpoint, an athlete with well-functioning hamstrings may not perform well in the SLBT due to the inability of their gluteal muscles to execute the task. Consequently, subjecting them to an isolated knee flexor strengthening program may not be the most appropriate strategy. Conversely, a satisfactory SLBT score for an athlete undergoing HSI rehabilitation does not necessarily indicate that hamstring function has fully recovered. The action of the glutes in hip extension may be the decisive factor for

satisfactory performance, making a return-to-play decision based solely on the SLBT premature. Therefore, even if future studies validate the potential association between the SLBT and the endurance capacity of the complex responsible for hip extension, practitioners should be mindful that this test may not differentiate whether the endurance deficit lies in the gluteal or hamstring muscles.

The authors acknowledge limitations in the present study. Firstly, our findings pertain to the performance of a sample of recreational athletes, and caution should be exercised when extrapolating them to high-performance athletes. Secondly, conducting additional sessions to familiarize volunteers with each test was not feasible in this study. Conversely, the same evaluators conducted all assessments, with one responsible for the SLBT and the other for the isokinetic test, ensuring that volunteers received consistent instructions and verbal stimuli. Thirdly, the SLBT necessitates evaluators with the ability to analyze technique, provide feedback, and count repetitions. Therefore, it is possible that some inherent errors in this assessment may have occurred in determining the test interruption due to task failure.

CONCLUSION

There was no significant correlation between the SLBT score and the knee flexor endurance assessed in isokinetic conditions. Similarly, the between-limb symmetry found in the LSBT was not significantly correlated with those found in the knee flexor endurance test. Therefore, the SLBT should not be used as a clinical tool to assess the endurance capacity of the knee flexor muscles.

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ANEXOS

ANEXO A



Guide for authors

Your Paper Your Way

Types of paper

Before you begin

- Ethics in publishing
 - Informed consent and patient details
- Declaration of interest
 - Declaration of generative AI in scientific writing
 - Submission declaration and verification
- Use of inclusive language
 - Reporting sex- and gender-based analyses
- Conflictof interests
 - Authorship
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 - Reporting clinical trials (CONSORT)
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- Role of the funding source
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Preparation

- Queries
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- Peer review
- Double anonymized review
- Revised submissions
- Article structure
 - Essential Title Page Information - a separate Title Page should be uploaded during submission.
 - Structured abstract
 - Highlights
 - Keywords
 - Acknowledgements
- Additional information required for Research articles, Reviews and Masterclass articles
- Artwork
- References
- Supplementary material
- Research data
- Submission Checklist

After acceptance

- Online proof correction
- Offprints

Author inquiries

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Review Papers: Provide an in-depth and up to date critical review of a related topic and will not normally exceed 4000 words.

Case Studies: A case report providing clinical findings, management and outcome with reference to related literature.

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<https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/>

. Adopted by the 18th World Medical Assembly, Helsinki, Finland, June 1964, amended by the 29th World Medical Assembly, Tokyo, Japan, October 1975, the 35th World Medical Assembly, Venice, Italy, October 1983, and the 41st World Medical Assembly, Hong Kong, September 1989. EU Directive 2010/63/EU for animal experiments

http://ec.europa.eu/environment/chemicals/lab_animals/legislation_en.htm;

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New guidance for randomised controlled trials

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Abstract

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