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RESEARCH ARTICLE

DEVELOPMENT AND VALIDATION OF THE ILIOPSOAS ENDURANCE TEST: A RELIABLE TOOL FOR CLINICAL AND FUNCTIONAL ASSESSMENT

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ABSTRACT

Purpose: The iliopsoas muscle complex is vital for lumbar stabilization, posture, and hip flexion, yet its endurance is often overlooked in clinical and research settings. This study aimed to develop and validate the Iliopsoas Endurance Test (IET), a cost-effective and practical method for assessing iliopsoas endurance.
Material and Methods: Fifty-three healthy adults aged 18–38 years (91% female) were included. Participants completed the IET under standardized 80° hip-flexion conditions. In addition, hip-flexion endurance was assessed using an isotonic mode of an isokinetic dynamometer (Biodex System 4 Pro). Intra- and inter-rater reliability were evaluated using ICCs, and criterion validity was examined by correlating IET repetitions with dynamometer-based endurance measurements.
Results: The IET demonstrated excellent intra-rater reliability (ICC = 0.802 for Assessor 1) and good intra-rater reliability (ICC = 0.701 for Assessor 2). Inter-rater reliability was excellent, with ICC values of 0.909 and 0.982. Strong correlations were observed between IET repetitions and isotonic dynamometer measurements for peak torque ($r = 0.706$, $p < 0.001$) and total repetitions ($r = 0.629$, $p < 0.001$). These findings support the IET as a reliable alternative to isotonic dynamometer-based endurance testing, particularly in settings where access to specialized equipment is limited.
Conclusion: The IET demonstrated excellent intra-rater reliability (ICC = 0.802, $p < 0.001$) and good intra-rater reliability (ICC = 0.701, $p = 0.003$), supporting its statistical robustness. The IET is a practical, reliable, and valid tool for assessing iliopsoas endurance, with potential applications in clinical diagnostics, rehabilitation, and performance analysis. Future research should explore its applicability across diverse populations and its role in long-term rehabilitation outcomes.

Keywords: Iliopsoas; hip flexion; endurance; isotonic dynamometer

INTRODUCTION

The hip flexors are an essential muscle group contributing to the maintenance of natural posture, lumbar stabilization, and various functional daily activities such as walking and transitioning from sitting to standing (1,2). This group, approximately

45–50 cm in length, consists of the psoas minor, psoas major, and iliacus muscles (3). The psoas minor originates from the lateral aspect of the T12-L1 vertebral bodies and intervertebral discs, merging into a weak tendon that integrates with the iliac muscle bundle, assisting in forward flexion of the lumbar spine (4). The psoas major originates from the transverse processes, lateral vertebral bodies, and intervertebral discs of T12-L4, terminating at the lesser trochanter of the femur (5). This muscle stabilizes the lumbar spine when the body is in an upright position and facilitates anterior pelvic tilt (6,7). The iliacus muscle is responsible for hip flexion and external rotation (8). While these muscles perform distinct functions, their simultaneous contraction results in active hip flexion (9). Weakness, spasm, or contractures within this muscle complex can lead to a range of clinical problems affecting the trunk and extremities. Overuse of the iliopsoas muscle can result in significant physiological changes, including increased muscle stiffness, adaptive shortening, and altered lumbopelvic alignment, particularly anterior pelvic tilt and increased lumbar lordosis. These biomechanical changes modify lower-extremity kinematics, leading to compensatory femoral internal rotation and reduced hip extension during gait (10). Such alterations increase patellofemoral joint stress and disrupt dynamic knee stability, predisposing individuals to knee pain, maltracking, and overload-related functional disorders. Given the iliopsoas muscle's proximal influence on knee mechanics, reduced endurance or excessive activation may contribute to the development or persistence of knee dysfunctions.

Injury to the iliopsoas muscle, whether acute or caused by overuse, is common across individuals with varying levels of activity (11). Specifically, acute groin, lumbar, and pelvic pain, snapping hip, vertebral alignment disorders, and acetabular labral impingement are common orthopedic problems associated with this muscle group. Furthermore, due to its anatomical connection to the diaphragm, the iliopsoas can directly influence respiratory function (8,12,13). Additionally, iliopsoas weakness during gait contributes to anterior pelvic tilt, leading to impaired stabilization (10). Beyond orthopedic problems, in the geriatric population, diminished iliopsoas muscle strength is linked to reduced step length, slower walking speed, and an increased risk of falls (14,15).

The evaluation of the iliopsoas muscle complex in diagnostic and therapeutic processes is often overlooked. Existing studies primarily focus on the muscle's shortness, flexibility, and weakness (12,16,17). However, there is a notable lack of research on the endurance capacity of the iliopsoas. Although the iliopsoas muscle is essential for hip flexion, lumbopelvic stabilization, walking, and functional daily tasks, clinicians often lack a simple and objective method to evaluate its endurance in routine practice. Existing assessments frequently focus on flexibility or strength rather than endurance, despite endurance being a critical component influencing posture, dynamic stability, injury risk, and lower-extremity biomechanics. This clinical gap highlights the need for a practical, equipment-free tool that can be used in diverse settings. Despite the functional importance of the iliopsoas, the literature provides limited methods specifically targeting the endurance capacity of this muscle complex. Current endurance tests either lack standardization, rely on compensatory muscle activation, or require expensive isokinetic dynamometers that are not accessible in most clinical environments. To our knowledge, no standardized field test has been developed or validated to assess iliopsoas endurance in a reliable and reproducible manner. In contrast to commonly used tests such as the Straight Leg Raise (SLR), Resisted Hip Flexion, or sit-up–based endurance tasks—which are influenced by abdominal fatigue, compensatory muscle activation, or lack specificity for the iliopsoas—the IET was specifically designed to isolate the hip flexor endurance within a controlled 80° hip-flexion range. Unlike dynamometer-based assessments, which require costly equipment and specialized training, the IET offers a standardized, equipment-free, and clinically accessible approach that minimizes compensatory movements and enables reproducible assessments across different evaluators. Therefore, this study aimed to develop a clinically applicable endurance test for iliopsoas muscle and to examine its intra-rater, inter-rater reliability, and criterion validity against isotonic measurements obtained from an isokinetic dynamometer.

Hypotheses:

i. The IET will demonstrate good to excellent intra-rater reliability.
ii. The IET will demonstrate good to excellent inter-rater reliability.

iii. Performance on the IET (number of repetitions) will show a significant and positive correlation with isotonic dynamometer hip-flexion endurance measurements (peak torque and repetition count).
iv. The IET will demonstrate acceptable criterion validity when compared with isotonic dynamometer–based endurance assessment.

MATERIAL AND METHODS

Study Design, Participants and Sample Size

This methodological study was approved by the Marmara University Faculty of Medicine Clinical Research Ethics Committee (Date: 01.04.2022, No: 09.2022.650). All participants were verbally informed about the study, and written consent was obtained. The study was conducted in compliance with the Declaration of Helsinki.

Healthy individuals aged 18–38 years with no evidence of lumbar extensor, hamstring, gastrocnemius, or iliopsoas shortening were included. Individuals with known neurological or cardiopulmonary diseases, lower extremity injuries or surgeries in the past year, acute and/or chronic low back pain, iliotibial band syndrome, trochanteric bursitis, femoroacetabular impingement syndrome, sacroiliac pain or dysfunction, or any rheumatological condition were excluded.

Jeon's pilot study was used as a reference for calculating the sample size for this study (18). The effect size in this study was 1.27, and the minimum required sample size was 15. More participants than the required sample size were invited to account for the possibility of dropouts. A total of 29 participants were included in the study between September 2022 and September 2023. Isokinetic dynamometry and initial assessments were analyzed with 29 individuals. For ICC values, the initial and final test data of the 23 individuals who participated in the second assessment were compared. Table 1 shows the patient data used in the test-retest analyses.

Assessments

Demographic Data Form: The demographic data form was prepared by researchers. This form recorded the participants' age, weight, height, body mass index (BMI), gender, and dominant extremity. In our study, body weight was assessed using a calibrated digital scale, with participants wearing light clothing and no shoes. Height was measured using a wall-mounted stadiometer, with participants standing upright without shoes and with their heads in the Frankfurt plane.

Development of the Iliopsoas Endurance Test (IET): Participants were positioned supine on a bed placed against a wall, with a pillow under their head. While the patient was lying in this position, they were asked to flex her hips 80 degrees and this angle was measured with a digital goniometer. In this degree, the distal end of the femur is used as a reference point to mark the position on the wall. A vacuum-anchored pointer was then placed at the marked location.

Before the test, both lower extremities were allowed to hang off the edge of the bed with the knees flexed. The test was performed using the dominant leg. Participants were instructed to ensure that their dominant knee touched the fixed pointer during the test, while avoiding contact between the distal end of

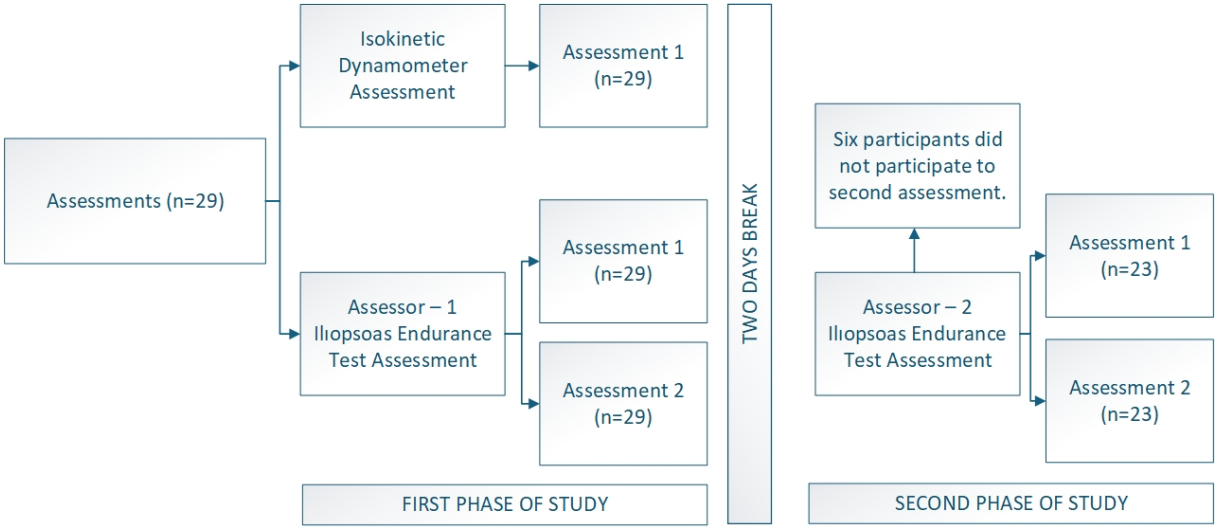


Figure 1. Study design

the posterior thigh and the bed when returning to the starting position. This restriction aimed to prevent acceleration of the lower extremity due to ground reaction forces. Participants were then asked to perform hip-flexion/extension movements as quickly as possible for 60 seconds. The test was terminated if the participant failed to touch the pointer twice consecutively or if the distal thigh contacted the bed. The number of contacts with the marker was recorded as the number of repetitions. Measurements were repeated with a two-hour interval between trials. A second evaluator performed the measurements two days after the initial evaluation (Figure 1).

Isotonic Hip Flexion Endurance Assessment: In this study, hip flexion endurance was evaluated using the Biodex System 4 Pro Dynamometer (Biodex Medical Systems 4 Pro, Shirley, New York, USA). The seat of the isotonic dynamometer was reclined, and the rotational axis of the hip joint was aligned with the rotational axis of the dynamometer shaft. The adapter attachment point of the dynamometer was fixed approximately 5 cm proximal to the dominant extremity's knee. The dynamometer was operated in isotonic mode, with resistance set to 25% of the participant's body weight. Therefore, although the device is an isokinetic dynamometer, the test itself was performed as an isotonic (concentric) endurance assessment. During the test, only the agonist muscle group (hip flexors) was targeted, no resistance was applied to the antagonist muscles.

The literature indicates that torque generation by the iliopsoas muscle increases at hip flexion angles above 30 degrees, with the moment arm reaching its peak between 70 and 80 degrees (11). For this reason, a range of motion from 0 to 80 degrees for hip flexion and extension movements was defined. Participants were instructed to perform hip flexion as rapidly as possible within this range while maintaining the knee in a flexed position. Patients made three trials at the device without encountering any resistance. To prevent trunk involvement during the movement, participants were required to hold onto the side handles of the dynamometer. For the test, resistance was set to 25% of the participant's body weight. The test was terminated if participants failed to achieve 80 degrees of hip flexion twice consecutively. Peak torque and the number of repetitions were recorded.

The assessments began with isotonic (concentric) endurance measurements. Three hours later, the first evaluator conducted the IET.

Statistical Analysis

Demographic data were summarized using mean, standard deviation, and percentages. Inter- and intra-rater reliability of the IET was assessed using Intraclass Correlation Coefficients (ICC), calculated using a two-way mixed-effects model, absolute-agreement type, single-measure form [ICC(3,1)] in accordance with Koo & Li (19). For criterion validity, the relationship between IET performance and isotonic dynamometer measurements was examined using Spearman's correlation coefficients. The strength of correlation coefficients was interpreted, where 0.20–0.39 indicates a weak correlation, 0.40–0.59 a moderate correlation, 0.60-0.79 strong correlation and values above 0.80 a very strong correlation (20). Since each participant underwent four separate IET measurements (two assessors × two sessions), the first measurement of the first assessor was selected for the validity analysis to provide a consistent reference across participants. All statistical analyses were performed using SPSS version 11, and the level of statistical significance was set at $p < 0.05$.

RESULTS

The study included a total of 23 participants, with a mean age of 21.47 ± 0.51 years. The mean body mass index (BMI) was calculated as 22.67 ± 2.88 kg/m². Of the participants, 95.65% were female, and the majority had right-dominant extremities (95.65%). Demographic details are presented in Table 1.

Table 1. Demographic characteristics of participants

Age (Years)	21.47 ± 0.51
Weight (kg)	58.70 ± 8.79
Height (meters)	1.66 ± 8.84
Body Mass Index (kg/m^2)	22.67 ± 2.88
Gender, n (%)	
Female	22 (95.65)
Male	1 (4.35)
Dominant Extremity	
Right	22 (95.65)
Left	1 (4.35)

Table 2. Results of Intra-rater and Inter-rater Analysis for IET

Assessors	IET			
	Assessment 1	**Assessment 2**	**ICC [95% CI]**	**p**
Assessor 1	60.13 ± 9.34	62.30 ± 8.18	0.802 [0.528-0.915]	<0.001
Assessor 2	63.96 ± 9.99	65.52 ± 7.47	0.701 [0.291-0.872]	0.003
ICC [95% CI]	0.909 [0.785-0.961]	0.982 [0.958-0.992]	-	-
p	<0.001	<0.001	-	-

ICC: Intraclass Correlation Coefficient; SD: Standard Deviations

Data on intra-rater and inter-rater reliability are presented in Table 2. The ICC values were 0.802 for Assessor 1 (95% CI: 0.528–0.915; p<0.001) and 0.701 for Assessor 2 (95% CI: 0.291–0.872; p=0.003), indicating excellent and good agreement, respectively. The inter-rater reliability between the two assessors demonstrated ICC values of 0.909 and 0.982, both reflecting excellent agreement (p<0.001). Details of the correlations between IET performance and isotonic dynamometer measurements are presented in Table 3. According to the results of the isotonic hip flexion endurance assessment, the participants' peak torque values were 71.07 ± 26.18 N-m. According to the classification, a strong correlation was observed between the peak torque values and the IET repetitions (r=0.706; p<0.001). The average number of repetitions performed during dynamometer measurements was 58.09 ± 4.63, showing a strong correlation with the IET results (r=0.629; p<0.001). These significant correlations indicate that the IET demonstrates strong criterion validity when compared with isotonic measurements.

DISCUSSION

This study examined the reliability of a newly developed field test for the iliopsoas muscle complex and its correlation with isotonic evaluation results. The findings demonstrated that the IET possesses excellent inter- and intra-rater reliability. Additionally, a strong correlation was found between IET results and isotonic dynamometer measurements, supporting the use of the IET as a practical and clinically applicable test. The reliability values obtained in the present study are consistent with previous research evaluating hip flexor or proximal lower-extremity endurance using clinical field tests (21). In our study, intra-rater reliability demonstrated good to excellent agreement (ICC = 0.701–0.802), which is comparable to the reliability range reported for similar functional hip-flexor tests (ICC = 0.67–0.89) in earlier methodological studies. Likewise, the inter-rater reliability of the IET (ICC = 0.909–0.982) aligns with the excellent reliability values frequently reported in standardized hip-strength and endurance assessments, where ICC values are typically above 0.90. In terms of validity, the strong correlations observed between the IET repetitions and isotonic dynamometer outcomes (r = 0.706 for peak torque and r = 0.629 for repetitions) are consistent with previous literature reporting moderate to strong associations (r = 0.50–0.75) between field-based endurance tests and dynamometer-based performance measures (21,22). These similarities indicate that the statistical performance of the IET is comparable to existing validated assessment tools, further supporting its applicability as a reliable clinical test. The strong correlations between IET performance and isotonic dynamometer outcomes further confirm the criterion validity of the test.

Although the IET demonstrated generally strong reliability and validity, some results showed comparatively lower coefficients, which may be explained by physiological and biomechanical factors. The moderate intra-rater reliability observed in Assessor 2 (ICC = 0.701) may reflect inherent variability in neuromuscular activation of the iliopsoas, as endurance tasks involving repetitive hip flexion are sensitive to fluctuations in motor-unit recruitment, trunk-pelvic stabilization, and movement pacing. Even small differences in pelvic alignment, verbal cues, or voluntary control of hip-flexion speed may contribute to performance variability despite standardized procedures. Furthermore, the strong but not perfect correlations between IET repetitions

Table 3. Correlation between Isotonic Dynamometer Assessment and IET

Test	Variables	IET Assessment 1		
		Mean ± SD	r	p
Isotonic Dynamometer	Peak Torque (N-m)	71.07 ± 26.18	0.706	<0.001
	Repetition (number)	58.09 ± 4.63	0.629	<0.001

IET: Iliopsoas Endurance Test; N-m: Newton-Meters; SD: Standard Deviations

and isotonic dynamometer outcomes likely stem from differences in contraction characteristics: the IET relies on body-weight–supported dynamic hip flexion in an open-chain position, whereas isotonic dynamometry imposes a fixed external load with constrained joint mechanics. These natural physiological discrepancies between field-based and externally loaded endurance tasks may partially explain the observed divergence in statistical values.

In the study, participants were asked to perform the maximum number of hip flexion-extension movements within a 0–80 degree range while in a supine position for one minute. The literature indicates that torque generation by the iliopsoas muscle increases at hip flexion angles above 30 degrees, with the moment arm reaching its peak between 70 and 80 degrees (11). This mechanical advantage enables the iliopsoas to perform hip movements more efficiently. The high torque production and pelvic stabilization provided by the iliopsoas during hip flexion are critical not only for daily activities but also for athletic performance (23). The iliopsoas is a multifunctional muscle group required for essential movements such as hip flexion, lumbar stabilization, walking, stair climbing, squatting, and maintaining an upright posture (24). However, studies evaluating the endurance capacity of the iliopsoas muscle complex are limited. This study aimed to address this gap by developing a cost-effective, equipment-free, and easy-to-apply test. These attributes make the IET particularly suitable for field studies and clinical settings.

Endurance, broadly defined as the ability of a muscle to sustain effort over time, is a key component for performing daily activities and maintaining functional independence (25,26). Various contraction types are used to measure endurance, with concentric and isotonic contractions being preferred in assessment tools to minimize injury risk (27). While isotonic evaluation devices are highly reliable for assessing muscle performance due to their ability to provide objective data and reduce injury risks, they are costly, require specialized expertise, and are not readily accessible (28). This underscores the need for alternative clinical assessment methods to evaluate the endurance capacity of the iliopsoas muscle. The strong correlation between IET and isotonic dynamometer evaluation results suggests that the IET can serve as an alternative to dynamometers. Furthermore, the IET requires participants to lift and control the weight of their lower limb in a closed-chain–free position. Because the movement is performed without assistance from ground reaction forces, compensatory momentum is minimized, which may enhance the consistency and accuracy of the endurance measurement. Various methods exist to assess the endurance of the iliopsoas muscle, each with distinct advantages and limitations. SLR test is a fundamental method for isolating the iliopsoas, requiring the individual to hold one leg straight in the air while in a supine position. Its simplicity and lack of equipment make it a preferred choice in clinical settings. However, compensatory activation of other muscle groups and early fatigue due to pain can compromise the accuracy of the results (23). The Resisted Hip Flexion Test measures muscle endurance against applied resistance, offering a more comprehensive approach by evaluating both strength and endurance. However, standardizing resistance and the subjective nature of assessments are significant limitations (23). The sit-up test, widely used to evaluate the endurance of the hip flexor muscles, requires the coordinated activation of abdominal and hip flexor muscles. Yet, the abdominal muscles' fatigue may lead to compensatory activity by the hip flexors, reducing the test's validity. Additionally, the activation of hip flexors during sit-ups can impose stress on the lumbar spine, increasing the risk of back pain (23,29). Therefore, caution should be exercised when administering the sit-up test, and complementary assessments may be needed for more reliable results.

Dynamic movement-based tests offer a functional context for evaluating iliopsoas endurance. Methods involving high-knee movements are particularly relevant for performance analysis in athletes. However, challenges in standardizing these movements and the potential stress on joints limit the applicability of such tests (28,30). The choice of a method for assessing iliopsoas endurance should depend on the individual's needs, physiological condition, and the purpose of the test. Simpler, equipment-free tests may be preferred for clinical evaluations, while dynamic and functional tests may be better suited for performance analyses.

The strength of this study includes the use of the Biodex dynamometer, an objective measurement tool, for evaluating hip flexion endurance. However, certain limitations should be noted. First, the study population consisted of young and healthy individuals, and the applicability of the IET in older adults or those with orthopedic problems was not assessed. Second, the isotonic dynamometer assessment was limited to a 0–80 degree range of motion. In addition, resistance during the isotonic dynamometer assessment was set as 25% of body weight rather than limb weight. Using limb weight could provide a more individualized loading strategy, and future studies should consider this approach. Moreover, as existing tests for iliopsoas evaluation are not specifically designed for this muscle group, comparisons were made with objective isotonic dynamometer measurements rather than these tests. Taken together, the reliability and strong criterion validity outcomes support the IET as a valid clinical assessment tool. Finally, gender distribution was not normal.

CONCLUSION

In conclusion, the IET emerges as a practical, cost-effective, reliable, and valid tool for assessing the endurance capacity of the iliopsoas muscle. Its applicability in clinical practice and rehabilitation processes offers valuable contributions to the diagnosis and treatment of iliopsoas-related problems. As a specific hip flexor endurance test that can be readily implemented in clinics, future research is recommended to explore the IET's use in diverse populations and its effectiveness in long-term rehabilitation programs.

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