DOI: 10.48305/jrrs.2024.42597.1087 Published by Vesnu Publications

The Intra-rater and Inter-rater Reliability of Intrinsic Foot Muscle Test in People with Flexible Flat Feet: Psychometric Study

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Original Article

Abstract

Introduction: Intrinsic foot muscles play an essential role in supporting the medial-longitudinal arch and maintaining its stability. In individuals with flexible flat feet, the activity of these muscles decreases, leading to functional impairment. Therefore, assessing the performance of the intrinsic foot muscles is critical for evaluating and monitoring the treatment progression in these individuals. The test commonly used today to determine the performance of these muscles is the intrinsic foot muscle test. However, to make clinical decisions based on this test's results, its reliability must be established. Therefore, our study aimed to investigate the intra-rater and inter-rater reliability of the intrinsic foot muscle test in individuals with flexible flat feet.

Materials and Methods: In this study, the intrinsic foot muscles test was performed on 30 young women with flexible flat feet, based on the Arch Height Ratio test. The assessment interval was one week for both raters. The quadratic weighted kappa test was used to evaluate intra-test and inter-test reliability. The results of each foot test were analyzed separately.

Results: The intra-rater reliability based on the Kappa coefficient for the first rater was 0.508, and for the second rater was 0.492. Additionally, the inter-rater reliability for pre- and post-assessment was 0.472 and 0.481, respectively.

Conclusion: According to the results of this study, the intra-rater and inter-rater reliability of the intrinsic foot muscles test was moderate. However, this test is the only one that evaluates the function of the intrinsic foot muscles in maintaining the medial-longitudinal arch and can be easily performed in clinical settings. Also, the therapist's clinical experience and proper training of individuals before performing this test are crucial.

Keywords: Pes Planus, Foot Arch, Physical exam, Rehabilitation, Psychometrics

Citation: Abolhasani S, Boozari S, Farjad Pezeshk A. **The Intra-rater and Inter-rater Reliability of Intrinsic Foot Muscle Test in People with Flexible Flat Feet: A Psychometric Study.** J Res Rehabil Sci 2024; 20.

Received date: 31.12.2023 Accept date: 04.02.2024 Published: 03.04.2024

Introduction

Among the anatomical structures of the foot, the plantar arches play the most critical role in the absorption and distribution of forces, as well as the maintenance of body stability. Among these, the Medial Longitudinal Arch (MLA) is of particular significance (1, 2). This arch is actively supported by the intrinsic and extrinsic muscles of the foot, and its collapse results in flat-foot (2). In individuals with flat feet, the activity of the abductor hallucis—an intrinsic foot muscle—is reduced (3-7). Weakness of the intrinsic muscles in flat feet can lead to reduced foot function (8, 9). Therefore, accurate assessment of these muscles' function is essential for therapists.

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Various laboratory tests, including dynamometry (10), electromyography (EMG) (11), and ultrasonography (9), are employed to assess the function of intrinsic foot muscles. Nevertheless, these methods are not readily available and necessitate a laboratory environment and specialized equipment. Furthermore, no valid and reliable clinical assessment method that is directly applicable in clinical settings has been reported to date (2, 12). Another critical point is that these tests primarily focus on the force-generating role of the intrinsic muscles during toe flexion, while disregarding their contribution to supporting the plantar arches (2). Consequently, there is a need for functional tests that assess the stabilizing role of these muscles in maintaining the plantar arch, and that can be readily performed in clinical settings.

Intrinsic foot muscles function as local stabilizers, playing a predominantly stabilizing role rather than a primary role in active movement (13). These muscles regulate joint motion and maintain physiological alignment by increasing stiffness (2, 13). Thus, their contribution to the structural support and stability of the plantar arch outweighs their role in force production (2). To assess their functional capacity to maintain the medial longitudinal arch, the Intrinsic Foot Muscle Test was developed (14) and has since been employed in various studies to evaluate foot performance (2, 15, 16). Given its ease of administration and independence from specialized laboratory hardware, this test holds potential for routine clinical use. Nevertheless, before integrating this test into clinical practice, its test-retest reliability must be established to ensure consistency over time. Additionally, inter-rater agreement between therapists should be investigated to verify the objectivity and reproducibility of the results.

Evaluating the reliability and reproducibility of any clinical assessment is crucial before its integration into practice. Reliability assessment ensures that results remain stable and dependable across repeated measurements over time or in different contexts (17). Consequently, the test's reliability was examined in a cohort of 25 healthy individuals of both genders. The findings demonstrated intra-rater reliability ranging from poor to fair, whereas inter-rater reliability ranged from fair to moderate (18). Nevertheless, that study was limited by a relatively small sample size and focused exclusively on individuals with neutral arch alignment. The authors recommended evaluating the test's reliability across populations with different foot morphologies, including those with low (Pes Planus) or high (Pes Cavus) arches.

Despite these considerations, there is a lack of research examining the reliability of this assessment in a flat-foot population. Given the high incidence of flat feet and the importance of intrinsic foot muscles in their management, this test would be highly valuable for clinical follow-up. However, verifying its reliability in subjects with flat feet is a necessary prerequisite for its clinical use. Additionally, since individuals with flat feet face greater challenges in maintaining their arch due to muscular insufficiency, the potential for error may be heightened. Consequently, this study aimed to investigate the intra- and inter-rater reliability of the Intrinsic Foot Muscle Test specifically in a flat-footed cohort.

Materials and Methods

This study was a psychometric investigation. Based on previous literature, 30 young female volunteers with flat feet were recruited (19-22). Participants were invited through advertisements in female dormitories at Tehran University of Medical Sciences. This study focused exclusively on women because they generally exhibit smaller muscle fiber cross-sectional areas and lower strength than men (23, 24), as well as higher ligamentous laxity and an increased risk of injury (25-27). The participants were aged 18 to 35 years, with arch height ratios ranging from 0.221 to 0.281. Exclusion criteria included: observable lower limb deformities, a history of surgery, trauma, or fractures in the foot, and any neurological or orthopedic conditions resulting in permanent lower limb alterations or affecting the individual's balance (16, 28-30).

Ethical Considerations: Before participation, all individuals read and signed an informed consent form that provided detailed information about the study's procedures. The Research Ethics Committee of Tarbiat Modares University approved this study and the consent process. Participants were informed of their right to withdraw from the study at any time without any consequences.

Arch Height Ratio (AHR) Test: The Arch Height Ratio test is recognized as one of the most reliable and valid methods for quantifying plantar arch height (31, 32). The Intraclass Correlation Coefficient (ICC) for both inter-rater and intra-rater reliability of this assessment has been reported to be at least 0.98 (32). In the present study, a custom-made device (ICC = 0.97) was utilized to measure the arch height ratio and identify the degree of flat-footedness among participants (33). The measurement was conducted by dividing the dorsal arch height (measured from the floor to the superior aspect of the foot at 50% of the total foot length) by the total foot length. Total foot length was defined as the distance from the posterior

aspect of the heel to the tip of the longest toe during quiet standing. According to the established criteria, an arch height ratio of less than 0.221 indicates flat feet, while a ratio between 0.221 and 0.281 is considered healthy (32). For this study, only individuals who met the criteria for flat feet were recruited as participants.

Functional Assessment of the Intrinsic Foot Muscles: In this study, the test-retest interval for assessing the intrinsic foot muscles was 1 week for each rater. Both raters were Master's students in Physiotherapy with three months of clinical experience in performing this specific test. The Intrinsic Foot Muscle Test is a clinical assessment designed to evaluate the functional performance of the intrinsic muscles during single-leg standing (14). This test measures the individual's ability to maintain the neutral position of the medial longitudinal arch height without resorting to compensatory movements. Before the primary assessment, participants were instructed on the correct technique for supporting the foot arch and performing the test. For the test procedure, participants were asked to stand facing a wall with their feet shoulder-width apart.

Additionally, they were instructed to place their index fingertips on the wall to maintain balance. To conduct the test, the examiner first passively extended the hallux to create the foot arch. Subsequently, the participant was instructed to actively support this position without flexing the toes or employing any compensatory movements. Compensatory movements in this test may include the recruitment of extrinsic flexor muscles (characterized by toe curling), the prominent protrusion of extrinsic extensor tendons, or applying excessive finger pressure against the wall to maintain balance (14). Once the participant was adequately trained, they were asked to extend the hallux to create the foot arch. While maintaining the arch height created, the subject was instructed to lower the hallux slowly. Simultaneously, while maintaining the arch height, the individual lifted the opposite foot off the ground and held a single-leg stance for 30 seconds, using only fingertip contact with the wall for balance (Figure 1).

The scoring and evaluation of the individual's performance were as follows:

- Acceptable functional score: The individual maintained a stable navicular height with minimal compensatory movements.
- Moderate functional score: The navicular height fluctuated periodically, with intermittent compensatory recruitment of the extrinsic muscles.
- Poor functional score: The navicular height was rapidly lost, and the individual was unable to maintain the arch height without resorting to compensatory movements (14).

Figure 1. Intrinsic foot muscle test procedure

Statistical Analysis: The Quadratic Weighted Kappa statistic was employed to evaluate both intra-rater and inter-rater reliability. The inter-rater kappa coefficient represents the level of agreement between the assessment results of two examiners for each limb within a single session. The intra-rater kappa coefficient indicates the degree of agreement for a single examiner's assessments of each limb across two separate sessions. The Kappa coefficient values range from -1 to +1. The interpretations of the Kappa coefficient (k) are categorized as follows: poor (less than 0), slight (0.01-0.20), fair (0.21-0.40), moderate (0.41-0.60), substantial (0.61-0.80), and almost perfect (0.81-1.00) (34, 35). The results obtained from both feet were entered into the statistical analysis separately. All data were analyzed using SPSS software (Version 22, IBM Corporation, Armonk, NY) with a 95% confidence interval.

Results

The demographic characteristics of the participants are presented in Table 1. Based on the findings, the intra-rater reliability Kappa coefficients for the first and second examiners were 0.508 and 0.492, respectively, indicating moderate reliability.

Furthermore, the inter-rater reliability Kappa coefficients for the pre- and post-assessments were 0.472 and 0.481, respectively, indicating moderate reliability.

Table 1. Demographic characteristics of the participants

Variables	Mean ± SD
Age (years)	27.33 ± 2.72
Height (m)	164 ± 4.96
Weight (kg)	56.64 ± 2.92
Arch Height Ratio (AHR)	0.19 ± 0.01

Discussion

Given the significance of intrinsic foot muscles in maintaining the medial longitudinal arch and the associated weakness of these muscles in individuals with flat feet, this study aimed to evaluate the reliability of the intrinsic foot muscle functional test in this population. Both intra-rater and inter-rater reliability were assessed. According to the findings of this study, both the inter-rater and intra-rater reliability of the intrinsic foot muscle functional test were within the moderate range.

In the healthcare and rehabilitation sectors, assessing both intra-rater and inter-rater reliability is crucial. These assessments validate the results of a clinical test, demonstrating their precision and consistency (17). In functional tests such as the intrinsic foot muscle test, which use subjective scoring systems, results depend heavily on the examiner's clinical judgment and expertise. Furthermore, the level of clinical experience in performing the test directly influences the outcomes. Consequently, achieving a high degree of reliability is not typically expected for such assessments. Despite the moderate reliability of the intrinsic foot muscle test, it remains the only suitable assessment for evaluating the stabilizing role and function of these muscles (2), as it is easily accessible and clinically feasible.

Furthermore, to date, no other functional test has been developed that can accurately assess the specific role of the intrinsic muscles in maintaining the arch. Different methods for evaluating the intrinsic foot muscles, such as electromyography (EMG), dynamometry, and ultrasonography (9-12), require a laboratory setting and are not clinically feasible. Moreover, even if these methods were applicable in a clinical context, their primary focus remains on the muscles' motor role, measuring their activity and strength during toe flexion. Consequently, the stabilizing role of these muscles in maintaining the foot arch is overlooked, even though, based on their anatomical and biomechanical structure, the intrinsic foot muscles do not possess a sufficient mechanical advantage to produce significant joint movement. Due to their anatomical position and alignment, these muscles transmit essential sensory information regarding changes in arch height to higher centers via the stretch response. Subsequently, they regulate arch height by adjusting their stiffness (2, 13). Therefore, their role in maintaining postural control and foot stability is more significant than their motor function; thus, an appropriate test must be utilized to assess the stabilizing performance of these muscles.

Our findings in this study are consistent with those reported by Facchini et al. in healthy individuals (18). However, in Facchini's study, intra-rater reliability was reported as poor to fair, while inter-rater reliability ranged from acceptable to moderate. Since the scoring system for this test is subjective, the examiners' skill level and expertise significantly influence the outcomes. In Facchini's study, the two examiners had no prior experience with the test and received only 3 hours of training before its administration. Furthermore, these examiners were physical education instructors and lacked clinical expertise.

Additionally, providing adequate instruction to participants prior to the primary assessment is paramount. This is because most individuals have limited awareness of how to activate these muscles and are unfamiliar with maintaining their arch height. Consequently, the examiner's clinical experience, proper instruction, and ensuring that participants have sufficiently learned the movement before the primary test are crucial factors. The lower reliability reported in Facchini's study may be attributed to insufficient participant training or the examiners' limited experience.

Furthermore, it appears that the intrinsic foot muscle test shares similar characteristics with sacroiliac joint assessment tests. Many of these tests also exhibit poor to moderate reliability (36-39), where the clinician's clinical experience significantly influences the outcomes. Nevertheless, these tests are still widely used in clinical settings to evaluate and diagnose sacroiliac joint dysfunction, as they are easily accessible and clinically feasible. On the other hand, in recent years, researchers have attempted to design newer sacroiliac joint tests with higher reliability to replace existing ones (40). Nevertheless, many of these tests continue to be used alongside other diagnostic methods as clinical tools for diagnosing and treating disorders. Consequently, the intrinsic foot muscle test can also be used to evaluate plantar muscle function and monitor patients' treatment progression in clinical settings.

Given the aforementioned points, it appears that possessing sufficient clinical experience in performing the intrinsic foot muscle test, along with providing proper and adequate instruction to participants, are key factors in enhancing the reliability of the results. Furthermore, despite its moderate reliability, this test retains significant clinical advantages, including its specific assessment of the stabilizing function of the intrinsic foot muscles, its lack of reliance on expensive laboratory equipment, and its simple administration. Therefore, with adequate experience and proper training, this test can be used in clinical practice until a more suitable functional test with higher reliability is developed to evaluate the intrinsic foot muscles.

Limitations

One limitation of the present study was that it was conducted exclusively with women. This selection was based on the fact that women typically exhibit lower muscle strength and greater ligamentous laxity, which increases their risk of injury. Nevertheless, for future studies, it is recommended that this test be evaluated in men as well to enhance the generalizability of the findings.

Recommendations

It is recommended that the scoring system for this test be modified from a 3-point scale to a 4-point scale, followed by a re-evaluation of its reliability. The "moderate" score encompasses a broad range of individuals; in the present study, the majority of subjects were categorized as moderate performers. Therefore, based on the degree of compensatory movements and navicular oscillations (shaking), the moderate score could be subdivided into two categories: Moderate Plus (Moderate +) and Moderate Minus (Moderate –). Furthermore, it is suggested that the test's reliability be investigated in other age groups, such as children and older people, as performing the test is more challenging for these populations, and the current findings may not be generalizable to them.

Conclusion

Based on the obtained results, the reliability (reproducibility) of the intrinsic foot muscle test is moderate. Nevertheless, this test can be easily administered in clinical settings and remains the only assessment to date that evaluates the function of the intrinsic muscles in maintaining the medial longitudinal arch. A critical factor in this test is that clinicians must have sufficient clinical experience to ensure the reliability of the results is not compromised. Furthermore, providing proper and adequate instruction to participants prior to the test is essential for maintaining reliability. Various healthcare professionals, including those in physical therapy, occupational therapy, physical education, physical medicine, and orthopedics, can use this test to assess and monitor patient treatment progression.

Acknowledgments

The authors would like to thanks all the participants who cooperated in the implementation of the aforementioned research project.

Authors' Contribution

Project design and conceptualization: Sargol Abolhasani, Sahar Boozari
Providing financial resources to carry out the project: Sahar Boozari
Project support, scientific and executive services: Sahar Boozari
Providing equipment and statical sample: Sargol Abolhasani
Data collection: Sargol Abolhasani
Analysis and interpretation of the results: Sargol Abolhasani, Sahar Boozari, Abbas Farjad Pezeshk
Critical statistics services: Sargol Abolhasani, Sahar Boozari
Manuscript preparation: Sargol Abolhasani, Sahar Boozari, Abbas Farjad Pezeshk
Specialized scientific evaluation of the manuscript: Sargol Abolhasani, Sahar Boozari, Abbas Farjad Pezeshk
Approving the final manuscript to be submitted to the journal: Sargol Abolhasani, Sahar Boozari, Abbas Farjad Pezeshk
Maintaining the integrity of the study process from the beginning to the publication, and responding to the reviewers' comments: Sargol Abolhasani, Sahar Boozari, Abbas Farjad Pezeshk

Funding

The present study was based on analysis of a part of the data extracted from the masters' theses in physiotherapy by Sargol Abolhasani (Registration code: 99975732, Ethics code: IR.MODARES.REC.1402.035 and IRCT code: IRCT20201128049511N5) and carried out with the approved budget of Master&#39 degree of Tarbiat Modares University.

The university did not interfere in data collection, analysis and reporting, manuscript preparation, and final approval of the study for publication.

Conflict of Interest

The authors did not have a conflict of interest

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