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Inter-rater reliability of a new instrument for measuring isometric strength of toe flexor muscle

Confiabilidade inter-avaliadores de um novo instrumento para medir a força isométrica dos músculos flexores dos pés

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ABSTRACT

The assessment of toe flexor muscle strength is an important factor in the analysis of the muscles that contribute to sustaining the longitudinal plantar arch. Intrinsic muscles have several functions such as providing support and stabilization to the arches of the foot, shock absorption, and rigidity for the transmission of forces and postural stability. **Objective:** To evaluate the reliability of a device to measure the isometric strength of the toe flexor muscles individually. **Method:** Methodological study with a quantitative approach to assess the reliability of the instrument for evaluating the maximum voluntary isometric strength of the flexor muscles of the toes individually. 20 feet of healthy volunteers were evaluated in two moments: initial evaluation performed by evaluator 1 and evaluation after one week performed by evaluator 2, to test the interclass reliability through the statistical test of Intraclass Correlation Coefficient (ICC). **Results:** The results showed excellent ICC in all toes with values ranging between 0.805 and 0.921. Toe 4 had the lowest standard error of measurement (SME) and minimal detectable change (MMD), demonstrating lower collection error and greater sensitivity. **Conclusion:** The proposed instrument is reliable for measuring the intrinsic flexor muscle strength of the foot, being an alternative for evaluating it in different populations, as it presents good reliability and reproducibility at an affordable cost, and can be used in future clinical studies and clinical practice.

Keywords: Foot, Muscle Strength, Muscles, Technological Development

RESUMO

A avaliação da força muscular flexora dos pododáctilos é um importante fator de análise dos músculos que contribuem para a sustentação do arco plantar longitudinal. Os músculos intrínsecos apresentam várias funções como fornecer suporte e estabilização aos arcos do pé, absorção de impacto e rigidez para a transmissão de forças e estabilidade postural. **Objetivo:** Avaliar a confiabilidade de um dispositivo para mensurar a força isométrica dos músculos flexores dos pododáctilos individualmente. Questão da pesquisa: Seria possível avaliar a força isométrica voluntária máxima dos músculos flexores dos pododáctilos de forma individual? **Método:** Estudo metodológico com abordagem quantitativa para avaliar a confiabilidade do instrumento de avaliação da força isométrica voluntária máxima dos músculos flexores dos pododáctilos individualmente. 20 pés de voluntários saudáveis foram avaliados em dois momentos: avaliação inicial realizada pelo avaliador 1 e avaliação após uma semana realizada pelo avaliador 2, para testar a confiabilidade interclasse por meio do teste estatístico Coeficiente de Correlação Intraclasse (ICC). **Resultados:** Os resultados demonstraram ICC excelente em todos os dedos com valores variando entre 0,805 e 0,921. O dedo 4 apresentou menor erro padrão de medida (EPM) e mínima mudança detectável (MMD) demonstrando menor erro de coleta e maior sensibilidade. **Conclusão:** O instrumento proposto é confiável para mensuração da força muscular flexora intrínseca do pé, sendo uma alternativa para avaliação da mesma em diferentes populações, pois apresenta boa confiabilidade e reprodutibilidade de custo acessível, podendo ser utilizado em estudos clínicos futuros e na prática clínica.

Palavras-chaves: Pé, Força Muscular, Músculos, Desenvolvimento Tecnológico

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Conflict of Interests
Nothing to declare

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INTRODUCTION

The foot and its 22 intrinsic muscles are a complex structure that presents a functional relationship between bones, ligaments, transverse tendons, neuromuscular feedback circuits, and muscles that work together to allow functional movement. Intrinsic muscles are completely contained in the foot, are small, and are difficult to assess functionally.[1] McKeon et al.[2] compared the intrinsic muscles of the foot with the abdominal and paraspinal muscles of the lumbopelvic nucleus of the hip, as this set of muscles is responsible for maintaining posture and providing stability to the body during gait. With each step, the foot's four layers of intrinsic muscles act to control the degree and speed of arch deformation. When they are not working properly, the base becomes unstable and misaligned, and abnormal foot movement occurs.

Intrinsic muscles have several functions such as providing support by maintaining and stabilizing the arches of the foot[2] playing an important role in the flexibility of the foot for impact absorption and its rigidity for the transmission of forces[3] in addition to postural stability.[4] They also provide stability and sensory input on which the primary movements (extrinsic muscles of the feet) depend to produce gross movement. Somatosensory input provided by the intrinsic foot muscles assists in motor planning as well as foot posture adaptations in balance and walking.[5]

Recent studies indicate that the decrease in the size and strength of the intrinsic muscles of the foot can reduce a person's ability to maintain balance during single-leg posture and physical performance.[4]

Weakness or atrophy of the intrinsic musculature of the foot has been associated with several pathological conditions including claw and hammer toe deformity, pes cavus, Charcot-Marie-Tooth, plantar fasciitis, hallux valgus, flatfoot, and diabetic peripheral neuropathy.[1,6,7]

However, to establish a relationship between muscle weakness and foot pathology, an objective measure of muscle strength is required.[7]

The importance of muscle strength tests focuses on detecting possible muscle imbalances. These, when in balance, contain the joint structures and provide the leverage conditions for movement and function to occur.[8]

The assessment of intrinsic muscle strength has been the subject of discussion to identify more reliable methods, given the difficulty in assessing it. Latey et al.[9] reported that the muscle strength of the feet depends on intrinsic and extrinsic muscles due to their architecture, making it difficult to measure intrinsic strength in isolation. Measurements of foot flexor muscle strength do not entirely differentiate between the force generated by intrinsic and extrinsic muscles because many of these intrinsic and extrinsic muscles follow similar lines of muscle action and have adjacent insertions, particularly in the forefoot.

A systematic review conducted by Soysa et al.[8] to evaluate different methods used to measure the intrinsic strength of the foot muscles, concluded that there is no "gold standard" in the evaluation of the quality of this musculature and categorized the methods as 'direct' or 'indirect'. According to the authors, the direct method measures the strength of the flexor muscles of the foot such as toe dynamometry, paper adherence test, plantar pressure, and the positive intrinsic test. Indirect methods are assessments that are unable to measure strength directly but provide information regarding intrinsic muscle structure (physiological cross-sectional area and volume), activity, and histochemical properties. They are magnetic resonance imaging (MRI), computed tomography (CT), ultrasonography (US), electromyography (EMG), and muscle biopsy.

Due to the importance of the toe flexor muscles in guaranteeing stability and balance to the body and the difficulty in evaluating this musculature with an adequate method.

OBJECTIVE

This study had the following objective: to propose an instrument to measure the isometric strength of the toe flexor muscles individually using a specific isometric dynamometer of easy reproducibility and low cost, where it was possible to combine the direct and indirect method and evaluate its inter-rater reliability.

METHOD

Methodological study with a quantitative approach carried out at the Laboratory of Biomechanics and Analysis of Human Movement at the Federal University of Alfenas (UNIFAL/MG). Approved by the Ethics and Research Committee (CAAE: 37265820.0.0000.5142).

The study had a convenience sample, that is, non-probabilistic, composed of 20 healthy individuals (mean age 28.29 years) from February 2022 to June 2022, recruited by invitation at UNIFAL/MG. Physically active volunteers aged between 22 and 45 years and of both sexes were included. Volunteers who agreed to participate signed a Free and Informed Consent Form (TCLE) before the procedure. Those who reported pain in any joint of the lower limb, surgeries in the last year, amputations or injuries in the last six months, pregnancy, concussion in the last three months, or contagious skin disease were excluded.

The single group (n: 20) was assessed on two occasions with a one-week difference between assessments so that the effect of one intervention did not overlap with the other. All evaluations took place in the same place and at the same time of day. The flexor muscles of the toes were evaluated individually through a traction system, where the volunteer performed the flexion movement with each toe, this one, laced with a rope. Data collection was carried out by two physiotherapist evaluators trained for this task and there was no communication between them during the evaluations. Evaluator 1 carried out the initial assessment and after an interval of one week, these same participants were evaluated again by evaluator 2.

For the study, a dynamometer was developed to assess isometric strength for the flexor muscles of the toes, modified from the instrument used by Kurihara et al.[10] This instrument belongs to the Laboratory of Biomechanics and Analysis of Human Movement (UNIFAL-MG). The apparatus consists of a rectangular platform with four supports coupled to a load cell in the center through a screw and nut fitting and connected to an electromyograph (Figure 1). This platform is 55 cm long, 33 cm wide, and 76 cm high. Under the top, the load cell was connected to a chain and a 35 cm handle where the toes were fitted individually to perform the traction force.

The great differential of the instrument was the individual assessment of each toe during the flexion movement, combining the direct and indirect methods suggested by Soysa et al.[8] For this, a load cell with a capacity of 200 kgf was used, connected to the electromyograph, model EMG System 830c (EMG System, São José dos Campos, São Paulo, Brazil), capable of obtaining muscle strength values.

To evaluate the intrinsic muscle strength of the foot, the volunteers were seated with the hips and knees at 90 degrees of flexion, and the ankle at neutral (0 degrees) according to Figure 2.

They were asked to remove their shoes and socks, leaving the feet and ankles evident. It was explained to the volunteers how the contraction of each toe would be collected and that only the laced toe would perform the contraction, without compensation for adjacent structures such as the ankle, knee, and hip. The loop was placed next to the metatarsophalangeal joint of each evaluated toe, where it was slightly extended.

The evaluators were positioned laterally to the evaluated foot to observe any movement compensation that might happen. The evaluators showed the volunteers the correct movement and this was trained before the collection. The volunteer was instructed to perform the movement at the examiner's command "strength", and he was asked to exert the greatest possible force. The muscle strength of the flexors of each toe was collected using three maximal voluntary isometric contractions (MVIC) of 10 seconds each, with a one-minute rest interval. This same evaluation was repeated one week later to compare the data between Evaluator 1 and Evaluator 2.

The physical integrity of the volunteers was safeguarded and their muscle comfort was ensured with minimizing measures in case there was pain and fatigue in the evaluated muscles. There was no discomfort in any volunteer.

Statistical analysis of the data was performed using the Statistical Package for Social Sciences (SPSS®) software (IBM® Corp., Chicago, USA), version 20.0, considering a significance level of 5% for both tests. The Intraclass Correlation Coefficient (ICC) was used to calculate the test-retest reliability. The values of maximum voluntary isometric strength minus the minimum force exerted at rest on each toe in three muscle contractions were subtracted from the electromyograph. From this number, the mean and standard deviation were extracted and the ICC between the evaluators was calculated. Reliability was considered excellent for ICC values greater than 0.75; moderate, between 0.40 and 0.75; weak, being less than 0.40.[11]

The standard error of the measurement (SEM) was calculated and, like the ICC, it is a measure of reliability.[12] The SEM involves calculating the variability of the measures of the same individual, being translated as the square root of the total variance excluding the variance between subjects.[13,14] This data is expressed by the same unit of measurement and was calculated by the formula below:

$$SEM = SD * \sqrt{(1-ICC)}$$

In addition, the minimum detectable change (MDC), considered a sensitivity measure, was calculated, which is described as the smallest variation of the measure that can be interpreted as a real change.[14] The MDC was calculated using the formula below:

$$MDC = 1{,}96 \times \sqrt{2} * SEM$$

RESULTS

The volunteers were asymptomatic and studied or worked at UNIFAL/MG, aged between 22 and 45 years, physically active, of both sexes and only one was left-handed. The means, standard deviations, and correlations of the three MVICs are described in Table 1.

Figure 1. Proposed device

Figure 2. Positioning the volunteer in the proposed instrument

DISCUSSION

The objective of this study was to measure the strength of the flexor muscles of the toes individually using a proposed instrument that combines the direct and indirect methods suggested by Soysa et al.[8] and test inter-examiner reliability. The strength measurements of the flexor musculature of each toe of both feet using the traction device showed excellent ICC in all relations. These analyses show the high test-retest reliability of the instrument developed using a load cell to assess the intrinsic musculature of the feet in healthy volunteers. Strength measurements of the intrinsic muscles of the feet are important, as these muscles participate in maintaining the longitudinal arch, ligament stability, and balance and body posture adjustments.[15]

Among the direct methods, toe dynamometry is an objective tool to measure toe flexor strength.[8] This technique, where the dynamometer is held stationary by an examiner or an external attachment and the volunteers push down with their toes,[16-19] demonstrated excellent intra-rater reliability with all ICC values greater than 0.83.[16-18] However, inter-rater reliability was only reported by Spink et al.[18] with excellent ICC values (ICC 0.82 - 0.88). A toe-curling action may occur during toe flexor testing, this action supposedly activates the long (extrinsic) toe flexors.

Garth & Miller[20] postulated, based on the anatomical insertions of the intrinsic muscles of the foot, mainly the interossei and lumbricals, that the interossei of the foot contract as a group to produce flexion at the metatarsophalangeal joint and extension at the interphalangeal joint. This is in contrast to flexion at the metatarsophalangeal and interphalangeal joints which is an action of the long (extrinsic) flexors of the toes. This finding suggests that manual dynamometry can activate intrinsic muscles more effectively than other types of dynamometry, as it promotes metatarsophalangeal joint flexion and interphalangeal extension. Spink et al.[18] considered ankle positioning important when measuring toe flexor strength. The authors hypothesized that passively holding the ankle in maximal plantar flexion, and extrinsic toe flexors are less likely to influence the measurement.

Table 1. Values of mean, standard deviation, intraclass correlation coefficient, standard error of measurement, and minimum detectable change of the three MICCs

	MEDIA	SD	ICC	ICC LEVEL	95% CI	SEM	MDC
FINGER 1 - EV 1	5.464	0.64	0.805	EXCELLENT	0.508 – 0.923	0.342	1.621
FINGER 1 - EV 2	5.674	0.647					
FINGER 2 - EV 1	3.574	0.309	0.832	EXCELLENT	0.571 – 0.934	0.219	1.299
FINGER 2 - EV 2	3.624	0.487					
FINGER 3 - EV 1	3.646	0.383	0.897	EXCELLENT	0.737 – 0.959	0.394	1.741
FINGER 3 - EV 2	3.624	1.526					
FINGER 4 - EV 1	3.346	0.294	0.882	EXCELLENT	0.707 – 0.953	0.115	0.942
FINGER 4 - EV 2	3.574	0.324					
FINGER 5 - EV 1	3.304	0.377	0.921	EXCELLENT	0.804 – 0.968	0.119	0.957
FINGER 5 - EV 2	3.55	0.36					

Legend: EV: evaluation; SD: Standard deviation; ICC: Intraclass correlation coefficient; ICC classification level; 95% CI: Confidence interval; SEM: Standard error of measurement; MDC: Minimum detectable change. p> 0.05

Since these muscles are in a position of maximum shortening, they generate less force. This hypothesis is supported by the findings of Goldmann & Bruggemann[21] who reveal that the smallest moment of force was generated around the metatarsophalangeal joints when the extrinsic flexor of the toes was in a shortened position during maximum plantar flexion of the ankle and ankle. metatarsophalangeal joint. The authors suggested that the lower force moments were because the intrinsic, rather than the extrinsic, toe flexors were primarily producing the moment around the metatarsophalangeal joint.

In our study, the ankle was in a neutral position, which suggests that there was no measurement of the intrinsic musculature without interference from the extrinsic.

In addition to the analysis in healthy individuals, this type of instrument is of great importance in the evaluations of individuals with diseases involving the feet, such as deformity of the hammer and claw toes, cavus foot, flat foot, Charcot-Marie-tooth, peripheral neuropathy diabetes, plantar fasciitis and hallux valgus1 for example, contributing to the planning of the treatment of these pathologies.

The SEM assesses the expected random measurement error (data 'noise'), which may originate from the instrument, the evaluator, or the subject, that is, it may involve technological, biological aspects or even reflect changes in the physical and mental state of the subject.[13] The SEM value ranged from 0.394 (toe 3) to 0.115 (toe 4), making it possible to say that the measurement of toe 4 had a lower error (noise) than the other toes following a decreasing scale. From the SEM, the 95% MDC was calculated. The MDC is a sensitivity measure because it is from it that, in repeated measurements, it is verified whether the observed change in the value of the measurement is real, being very useful in clinical practice. The MDC value ranged from 1.741 (toe 3) to 0.942 (toe 4), also following a decreasing scale, which demonstrates greater sensitivity for toe 4.

Martins[22] describes that the reliability of an instrument is its coherence, determined through the constancy of the results. Kottner et al.[11] in their article where he proposes guidelines for reports and studies of reliability and agreement (GRRAS) defines reliability as the ability of a measurement to differentiate between subjects and objects.

In this aspect, the results of the present study demonstrate that the proposed instrument is reliable for measuring the intrinsic muscle strength of the foot, being an alternative for evaluating it in different populations.

Study limitations

As a limitation, we can mention the small sample size due to the pandemic period (COVID-19) in which this work was carried out, collection difficulties, and the epidemiological security of researchers and volunteers. Another limitation was the "Hawthorne Effect" because the evaluators knew that their interventions would be compared, that is, it may be that the evaluators' behavior was changed due to the knowledge of the comparison.

CONCLUSION

Currently, there is no method for measuring the intrinsic musculature of the foot that does not interfere with the extrinsic musculature during the evaluation. We proposed a new instrument where the evaluation is done by traction through a load cell with excellent measurement consistency, high reliability, and easy reproducibility.

Due to the importance of evaluating the intrinsic musculature of the foot, given its function for good body performance, and the various pathologies caused by its weakness, our instrument contributes by presenting a new consistent, and low-cost method, using reusable materials, requiring only the investment in the load cell and electromyograph. The present study presented how the instrument is made and how it can be used in future studies and clinical practice.

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