Agreement and reliability between two types of portable dynamometers: traction and compression

Concordância e confiabilidade entre dois tipos de dinamômetros portáteis: tração e compressão

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Abstract

Introduction: The measurement of quadriceps strength is crucial for various clinical applications. However, traditional isokinetic dynamometers are expensive and bulky. Handheld dynamometers represent accessible alternatives, but the agreement between compression and traction dynamometers in evaluating knee extensor torque requires investigation. **Objective:** To evaluate the agreement between handheld compression and traction dynamometers in knee extensor torque and to verify intra- and inter-examiner reliability. **Methods:** This is a methodological study with a convenience sample. Participants were recruited by researchers in the physiotherapy outpatient clinic of the Federal University of Juiz de Fora – University Hospital, between June 2021 and June 2022. Two dynamometers were used: the MMT manual dynamometer from Lafayette Instrument Company, and the E-lastic® 200 kg traction dynamometer. **Results:** The reliability of the dynamometers (compression and traction) was excellent, with high intra- and inter-examiner agreement (ICC(2,2) ranging from 0.94 to 0.99). No significant differences were observed between the dynamometers, indicating equivalence. The Bland-Altman plots also showed good agreement, and Student's t-tests did not detect significant differences between examiners. **Conclusion:** The handheld compression and traction dynamometers used in this study demonstrated high reliability and equivalence in measurements, allowing flexibility in choosing these instruments in clinical practice. Future research may explore evaluators' and patients' perceptions of these measurements.

Keywords: Lower limbs. Muscle strength dynamometer. Torque. Reproducibility of results.

Resumo

Introdução: *A mensuração da força do quadríceps é crucial para diversas aplicações clínicas. No entanto, os dinamômetros isocinéticos tradicionais são caros e volumosos. Os dinamômetros portáteis representam alternativas acessíveis, mas a concordância entre os dinamômetros de compressão e tração na avaliação do torque extensor do joelho requer investigação.* ***Objetivo:*** *Avaliar a concordância entre os dinamômetros portáteis de compressão e tração no torque extensor do joelho e verificar a confiabilidade intra e interexaminadores.* ***Métodos:*** *Trata-se de um estudo metodológico com amostra de conveniência. Os participantes foram recrutados por pesquisadores no ambulatório de fisioterapia da Universidade Federal de Juiz de Fora – Hospital Universitário, entre junho de 2021 e junho de 2022. Foram utilizados dois dinamômetros: o dinamômetro manual MMT da Lafayette Instrument Company e o de tração E-lastic® 200 kg.* ***Resultados:*** *A confiabilidade dos dinamômetros (compressão e tração) foi excelente, com alta concordância intra e interexaminadores (ICC(2,2) variando de 0,94 a 0,99). Não foram observadas diferenças significativas entre os dinamômetros, indicando equivalência. Os gráficos de Bland-Altman também apresentaram boa concordância e os testes t de Student não detectaram diferenças significativas entre os examinadores.* **Conclusão***: Os dinamômetros portáteis de compressão e tração utilizados neste estudo demonstraram alta confiabilidade e equivalência nas medidas, permitindo flexibilidade na escolha desses instrumentos na prática clínica. Pesquisas futuras podem explorar as percepções de avaliadores e pacientes sobre essas medidas.*

Palavras-chave: *Membros inferiores. Dinamômetro de força muscular. Torque. Reprodutibilidade dos resultados.*

Introduction

Quadriceps muscle strength is a critical indicator for assessing muscle function, monitoring clinical conditions, and predicting clinical outcomes in different populations, including mortality in certain pathological conditions.[1-3] The isokinetic dynamometer is considered the gold standard for assessing muscle strength. However, its high cost and large size limit its use in clinical practice.[4-6] Alternatively, portable dynamometers have been widely used in recent studies due to their affordability, ease of transport, and use.[7,8]

Previous studies using both manual compression and manual traction dynamometers have shown moderate to excellent validity compared to isokinetic dynamometers.[9-11] In addition, manual dynamometry has demonstrated good intra- and inter-examiner reliability.[12,13]

Despite the usefulness and validity of manual dynamometers, no studies have been conducted to investigate the agreement between compression and manual traction dynamometers in the assessment of knee extensor muscle torque. This study is necessary to fill this gap in the literature and provide evidence of the reliability of these instruments in clinical practice. Therefore, this study aims to investigate the agreement between manual compression and traction dynamometers in the assessment of knee extensor muscle torque, as well as to verify the intra- and inter-examiner reliability in the use of these dynamometers.

Methods

This is a methodological study with a convenience sample. Participants were recruited by researchers in the physiotherapy outpatient clinic from the Federal University of Juiz de Fora – University Hospital, between June 2021 and June 2022. The research was approved by the local Research Ethics Committee (protocol number 5,376,774). All participants who consented to participate in the research signed an informed consent form.

Sample

Participants aged between 18 and 60 years old, from both sexes, were included. Exclusion criteria were presenting pain or musculoskeletal discomfort in the lower limbs at the time of evaluation, orthopedic surgery and musculoskeletal injuries in the lower limbs in the last six months, neurological disorders, and those who could not perform the tests.

Sample size calculation

The sample size was estimated using the reference from Walter et al.,14 considering H0 = 0.4, H1 = 0.75, $\alpha = 0.05$, $\beta = 0.2$, n = 2, resulting in 33 individuals. We also observed the consensus-based standards for the selection of Health Measurement Instruments (COSMIN) recommendation of 50 individuals for a good sample size.[15]

Equipment

Two dynamometers were used: the handheld MMT Lafayette Instrument Company, model 01165 (Lafayette, IN, USA) with the unit of measurement in N (Newton), and the E-lastic® 200 kg traction dynamometer. The compression dynamometer was coupled to a stand designed and printed by a 3D printer, made of ABS polymer.

Assessment protocols

In the first evaluation, sociodemographic and clinical characteristics were collected (age, body mass, height, lower limb dominance, perimetry, and education level). Subsequently, isometric muscle strength tests for knee extensors of the dominant lower limb were conducted, determined by which leg participants would use to kick a ball.[16]

The tests were conducted by two experienced and previously trained physiotherapist examiners. They were blinded to the outcomes, as were the participants. Another researcher documented the results. The examiners and dynamometers order were randomized by a research team member not involved in data collection, using an algorithm developed for the statistical software R v.4.1.0 (R Core Team 2021). The second assessment was carried out within two weeks.[17]

One measurement on each dynamometer was performed for learning purposes. Participants were asked to perform a 5-second isometric contraction, and peak force values were recorded for two repetitions on the dominant limb. A rest interval of 30 seconds was given for muscle recovery between each repetition, and 3 minutes of rest were allowed for changes in test position to the other dynamometer.[18] During measurement, the examiner used a verbal command: "One, two, three, and now: push, push, push, push, push, and relax". A 5-minute rest was standardized between the evaluations of the examiners.[19]

The torque of the knee extensors (τ) in Newton meters (Nm) was calculated by multiplying the average of the two contractions force output ($\vec{F}$), with the unit of measure in N, by the lever arm ($\underline{d}_{\perp}$), according to the formula: $\tau = \vec{F} \times \underline{d}_{\perp}$.[20] The lever arm was calculated in meters, from the knee joint line to the point of the dynamometer application.[21]

Knee extensors with compression dynamometer

The participant was seated, with the hips and knees flexed at 90° and the arms crossed at chest level. An inelastic belt was fixed around the thighs to the chair. The dynamometer was positioned 5 cm above an imaginary bimalleolar line on the dominant leg and coupled to a PVC pipe affixed to the wall.[18]

Knee extensors with traction dynamometer

The participant was seated, with the hips and knees flexed at 90° and the arms crossed at chest level. An inelastic belt was fixed around the thighs to the chair. The dynamometer was attached to a carabiner, along with a chain on one end to a ladder rung and on the other end attached to a velcro strap, around the ankle, 5 cm above an imaginary bimalleolar line of the dominant leg.[5]

Statistical analysis

The data distribution was checked by the Shapiro-Wilk test, in which some variables were non-parametric. Bootstrapping procedures (1000 resamples; 95% BCa CI) were performed to obtain more reliable results, to correct deviations from normality in the sample distribution, in the paired sample t-test to verify whether the torque measurements from each examiner were different. Subsequently, descriptive analysis was used to present the characteristics of the participants.

Reliability was determined through the calculation of the intraclass correlation coefficient, two-way random model (ICC(2,2)), average measures, absolute agreement. The reliability coefficients were interpreted as poor (< 0.5), moderate (0.5 – 0.75), good (0.75 – 0.9), and excellent (> 0.9) reliability,[22] with $\alpha = 0.05$ and a 95% confidence interval. The standard error of measurement was estimated by the formula $SEM = \sqrt{MSE}$ for absolute agreement.[23] Apparently, the power of F-statistics is not altered by violations of normality.[24]

The Friedman test was conducted to investigate whether the measurements were equivalent; subsequently, the limits of agreement were investigated by the Bland-Altman plots of the first day measurements, displaying the mean and 95% confidence interval at 1.96 SD (standard deviation) above and below this mean of the difference between the compression and traction dynamometry evaluations by the examiners.[23]

Results

A total of 52 participants took part in the study; however, one participant did not complete the entire protocol, and one outlier was removed for exceeding more than twice the average of the participants. This way, the study comprised 50 participants, with 32 females and 18 males; 47 reported the right lower limb as being the dominant, and 3 the left lower limb. The sample characteristic data are presented in Table 1.

Intra-examiner and inter-examiner reliability

The intra-examiner reliability obtained for the compression dynamometer was considered excellent for both examiner 1 and examiner 2 (ICC(2,2) = 0.95 and 0.96, respectively). For the traction dynamometer, the intra-examiner reliability was also considered excellent for both examiners (ICC(2,2) = 0.95 and 0.94).

The inter-examiner reliability coefficients (ICC(2,2)) for both the compression and traction dynamometers were considered excellent for both examiners, ranging between 0.97 and 0.99 (Table 2).

Table 1 - Sample characterization (n = 50)

Variables	n (%)
Gender	
Female	32 (64)
Male	18 (36)
Education	
Complete high school	1 (2)
Complete college degree	25 (50)
Incomplete college degree	24 (48)
Dominant lower limb	
Right	47 (94)
Left	3 (6)
Body mass (kg)*	71.06 ± 19.25
Perimetry (cm)*	48.16 ± 7.48
Height (m)*	1.67 ± 0.89
Age (years old)*	31.28 ± 9.14

Note: *Data are reported as mean ± standard deviation.

Table 2 - Intra-examiner and inter-examiner reliability of traction and compression dynamometers (n = 50)

Dynamometer	Intra-examiner 1*	SEM	Intra-examiner 2*	SEM	Inter-examiner*	SEM
Traction	0.95 (0.91 – 0.97)	8.7	0.94 (0.9 – 0.97)	9.26	0.97 (0.95 – 0.98)	6.31
Compression	0.95 (0.92 – 0.97)	8.4	0.96 (0.93 –0.97)	8.2	0.97 (0.96 – 0.98)	6.02
Traction (day 2)	-	-	-	-	0.99 (0.98 – 0.99)	3.59
Compression (day 2)	-	-	-	-	0.98 (0.96 – 0.99)	5.59

Note: *ICC, 95%CI. ICC = intraclass correlation coefficient; CI = confidence interval; SEM = standard error of measurement.

The Friedman test was conducted to investigate whether the measurements were equivalent. The results were not statistically significant (χ^2 (7) = 1.98, p = 0.96), indicating that the measurements did not show significant differences.

Figure 1 shows the agreement of the dynamometers in the examiner's measurement using a Bland–Altman plot. For Examiner 1, the limits of agreement ranged from -20.79 to 21.09, while for Examiner 2, the range was from -28.00 to 22.92. In both analyses, most of the points are within the 95% limits, with scores evenly distributed.

Table 3 shows that there was no difference in the torque of the knee extensors between the examiners, both in the compression dynamometer and in the traction dynamometer.

Table 3 - Knee extensor torque in Newton meters (n = 50)

	Examiner 1	Examiner 2	T-test (p)
Traction (day 1)	81.39 ± 28.96	80.64 ± 28.52	0.54
Compression (day 1)	81.24 ± 29.67	83.17 ± 31.08	0.12
Traction (day 2)	81.01 ± 27.87	81.55 ± 29.70	0.48
Compression (day 2)	80.36 ± 29.11	81.01 ± 29.67	0.53

Note: Data are reported as mean ± standard deviation.

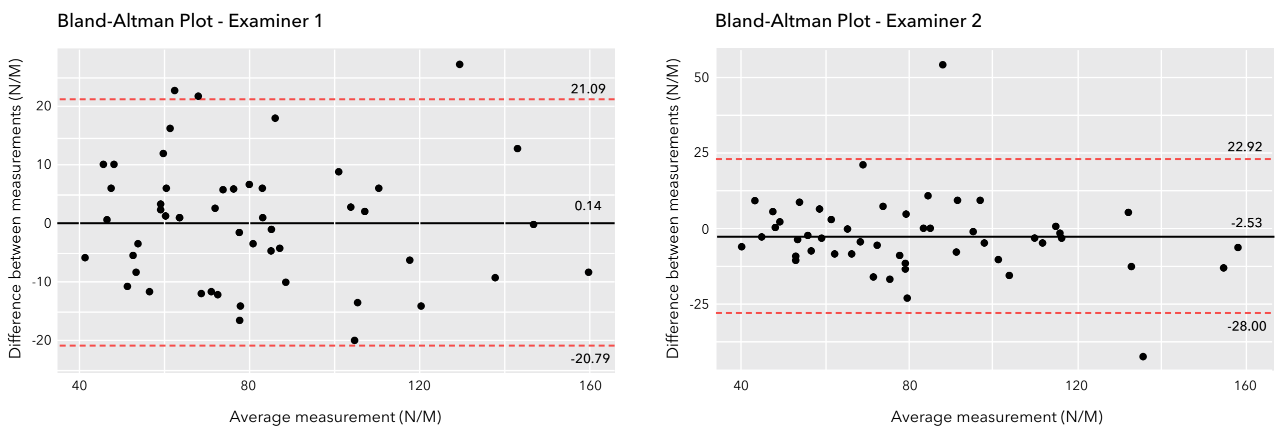

Figure 1 - Bland-Altman analysis conducted by examiners 1 and 2.

Discussion

This is a pioneering study investigating the agreement between two portable dynamometers assessing the knee extensors muscle torque. The results showed no significant differences in the muscle torque of the knee extensors measured with the compression and traction dynamometers, thereby obtaining agreement between the dynamometers measurements, presenting an excellent ICC.

The inter-examiner reliability coefficients obtained during the tests were considered excellent, both for the compression dynamometer (ICC(2,2) = 0.97) and for the traction dynamometer (ICC(2,2) = 0.97). The study by Luedke et al.[25] presented a moderate reliability (ICC(3,1) = 0.51) according to the classification used in our study,[22] however, a stabilization device was not used on the compression dynamometer, which may influence the measurement of the knee extensors torque. Some studies have shown that a stabilizing device causes greater reliability.[26,27] Similarly, Kelln et al.[28] observed good inter-examiner reliability (ICC 0.7 - 0.89) in the measurement of the knee extensors in young adults and physically active individuals, with the measurement being performed in a prone position and without stabilization on the compression dynamometer. Reliability can be affected by the inadequate force of the examiner and by the lack of stabilization of the participant and the device.[29,30] We infer that the measurement position may also interfere.

The intra-examiner reliability coefficients obtained for the compression dynamometer for examiners 1 and 2 were also considered excellent (ICC(2,2) = 0.95 and 0.96, respectively). It was observed that examiner 2 presented a higher average torque than examiner 1 with the compression dynamometer (83.44 Nm), but without statistically significant difference. We postulate some issues, such as the verbal command may have been more vigorous in the second assessment, or even the participants' desire to surpass the result of the first assessment, despite being blinded. Participants always inquired about the values of the measurements, but they were only able to check them at the end of the study.

Jackson et al.[18] observed the intra-examiner reliability of hand held dynamometry with the use of a portable stabilization device for lower limbs in an athletic population and found excellent intra-rater reliability for isometric muscle performance of the lower extremity including the hip abductors, external rotators, adductors, knee extensors, and plantar flexors of the ankle, with an average of the groups evaluated having an ICC(3,1) of 0.93 to 0.98.

The intra-examiner reliability for the traction dynamometer was considered excellent for both examiners (ICC(2,2) = 0.94). In this case, a device for stabilizing the dynamometer was not necessary, however, a strap was used to avoid compensatory movements of the participant. Peek et al.[30] used a traction dynamometer and found that it is a reliable method for assessing the hamstrings and quadriceps isometric muscle strength in elite youth soccer players. In the current study, the Bland-Altman limits of agreement for the traction and compression dynamometers conducted by both examiners were satisfactory, with scores distributed both above and below the average difference.

Portable dynamometers (traction and compression) are consistent and reliable tools in clinical practice, and the cost-benefit is advantageous. We recommend clinicians use stabilization in conjunction with the compression dynamometer in assessing the torque of the knee extensors, as both devices are consistent and reliable, and the choice depends on the evaluator's experience. We suggest that future studies evaluate the perceptions of patients and examiners.

The present study has limitations, the participants were selected by convenience sampling, and our results should be interpreted with caution and should not be extrapolated to athlete populations or those with musculoskeletal injuries in the lower limbs.

Conclusion

We can conclude that the compression and traction dynamometers demonstrated high reliability, and the measurements made by the examiners were equivalent and consistent for knee extensor torque. Furthermore, the dynamometers showed agreement. These results are important for the use of dynamometers in clinical practice, and the dynamometer choice can be left to the discretion of the evaluators, considering patient preference. We suggest that future studies evaluate the perceptions of evaluators and patients.

Authors' contributions

BLP, WOA and PMW contributed to the conceptualization of the study; WOA, to visualization; PMV, to methodology; BLP and PMV, to investigation; LFL and ACS, to resources and data curation; LFL, to project administration; BLP, LFL and WOA, to writing of the original draft; PMV and DSF, to supervision formal analysis, writing and review. All authors approved the final version of the manuscript.

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