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ORIGINAL RESEARCH

Reliability of the intra and inter-test measures with universal goniometer and podalic arthrometer of the active range of ankle inversion and eversion

Fidedignidade das medidas inter e intratestes com goniômetro universal e artrômetro podálico da amplitude ativa de eversão e inversão do tornozelo

Fiabilidad de las medidas inter y intra-ensayo con goniómetro universal y artrómetro podálico de la amplitud activa de inversión y eversión del tobillo

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ABSTRACT | The objective this study was to evaluate intra and inter-rater and inter-instruments reliability of ankle inversion and eversion active range of motion. The study included 100 healthy individuals (71 women and 29 men; ages: 21.32±2.83 years old; body mass: 60.40±4.95 kg; height: 1.66±0.04 m; and body mass index: 21.89±2.83 kg/m^2), who were submitted to measurement of ankle inversion and eversion using the universal goniometer and podalic arthrometer. We used the intra-class correlation coefficient (ICC) and Pearson's test, considering a 5% significance level. The results of this study demonstrated one very strong intra-rater ICC (0.91≥0.99; p<0.01) and a strong inter-rater (0.61≥0.9; p<0.01) in both the first and second measurements, especially when measured with the podalic arthrometer (ICC>0.8; universal goniometer: ICC<0.8). The inter-instruments correlation was proved as being regular and significant (0.31≥r≤0.6; p<0.01) for all evaluators and evaluations. Both tested instruments can be used in physical therapy practice for measurements of ankle inversion and eversion due to the high reliability presented, regardless of the evaluator's previous experience, especially the podalic arthrometer when compared to the universal goniometer, which is probably due to the lower influence that the appraiser has on the instrument during measurements.

Keywords | Arthrometry, Articular; Ankle; Reproducibility Of Results.

RESUMO | O objetivo deste estudo foi avaliar a confiabilidade das medidas intra- e interavaliadores e interinstrumentos da amplitude de movimento ativa de eversão e inversão do tornozelo. Participaram deste estudo 100 indivíduos saudáveis (71 mulheres e 29 homens; idade: 21,32±2,83 anos; massa corporal: 60,40±4,95 kg; estatura: 1,66±0,04 m; e índice de massa corporal de 21,89±2,83 kg/m^2), os quais foram submetidos à mensuração de inversão e eversão do tornozelo com goniômetro universal e artrômetro podálico. Foram utilizados o coeficiente de correlação intraclasse (CCI) e o teste de Pearson, considerando-se um nível de significância de 5%. Os resultados deste estudo demonstraram um CCI intra-avaliador muito forte (0,91≥0,99; p<0,01) e interavaliador forte (0,61≥0,9; p<0,01), tanto na primeira quanto na segunda medida, especialmente quando mensuradas com o artrômetro podálico (CCI>0,8; goniômetro universal: CCI<0,8). A correlação interinstrumentos mostrou-se regular e significante (0,31≥r≤0,6; p<0,01) para todos os avaliadores e avaliações. Ambos os instrumentos testados podem ser utilizados na prática fisioterapêutica para as medidas de inversão e eversão do tornozelo pela alta confiabilidade apresentada, independentemente da experiência do avaliador, especialmente o artrômetro podálico comparado ao goniômetro universal, provavelmente, pela menor influência que o avaliador exerce sobre o instrumento durante a medida.

Descritores | Artrometria Articular; Tornozelo; Reprodutibilidade dos Testes.

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RESUMEN | El objetivo del estudio fue evaluar la fiabilidad de las medidas intra e inter-evaluadores e inter-instrumentos de la amplitud del movimiento activa de eversión e inversión del tobillo. Participaron de este estudio 100 sujetos sanos (71 mujeres y 29 hombres; edad: 21,32±2,83 años; masa corporal: 60,40±4,95 kg; estatura: 1,66±0,04 m e índice de masa corporal: 21,89±2,83 kg/m^2), que fueron sometidos a la medición de inversión y eversión del tobillo con goniómetro universal y artrómetro podálico. Se utilizó el coeficiente de correlación intraclase (CCI) y la prueba de Pearson, teniendo en cuenta un nivel de significancia del 5%. Los resultados del estudio demostraron un CCI intra-evaluador muy fuerte (0,91≥0,99; p<0,01) y del inter-evaluador fuerte (0,61≥0,9; p<0,01), en la primera y en la segunda medición, especialmente cuando medidas con el artrómetro podálico (CCI>0,8; goniómetro universal: CCI<0,8). La correlación inter-instrumentos se mostró regular y significante (0,31≥r≤0,6; p≤0,01) para todos los evaluadores y evaluaciones. Los dos instrumentos probados pueden ser utilizados en las medidas de inversión y eversión del tobillo por su alta fiabilidad presentada, independientemente de la experiencia del evaluador. Sin embargo, las medidas del artrómetro podálico mostraron una mayor fiabilidad en comparación al goniómetro universal probablemente por la menor influencia que el evaluador ejerce sobre el instrumento durante la medición.

Palabras clave | Artrometría Articular; Tobillo; Reproducibilidad de Resultados.

INTRODUCTION

The range of motion (ROM) an articulation can reach is related to its morphology, capsule, ligaments and muscles and/or tendons crossing it[1], so that the measurement of this ROM is an important component in the identification of articulatory limitations[2], serving as a parameter in the monitoring of musculoskeletal and neurological disorders[3,4] and helping with motivation and adherence of the patient to the treatment, once it registers the effectiveness of the intervention, besides being an important criteria in the making of orthosis[5].

Given its importance, the ROM must be measured with precision and, in order to do so, it is essential it is evaluated by, non-invasive, reliable methods and tools, of easy use and which may be reproduced by different evaluators[6-9].

In this sense, the reliability of a measure is essential in order to ensure the consistency of the data, allowing its use in the evolution of protocols used in clinical physical therapy and in scientific researches[10]. Thus, it is imperative that there is concordance between measures of the same variable, the same individual and in the same conditions, comparing them to the reference patterns[11,12]. However, for Batista et al.[2], There are three sources of mistakes which may turn a measure into an unreliable one: the measurement instrument; the person performing the evaluations and the different characteristics of the volunteers being evaluated.

According to some studies[10,13], both the intra-rater (consistency of performed measures in the same analysis conditions at different moments) and inter-raters (consistency of performed measures by different evaluators) reliability need to be controlled through methodological Standards and according to the accuracy degree of different instruments, so that they are considered reliable.

The ADM measurement method considered as gold-standard by the literature is the radiography, however, it is not an usual tool in reliability studies, since, considering the need for revaluations, it would imply in excessive exposure of patients to radiation and in high cost for the services of health[14]. Therefore, many studies try to find reliable instruments (isokinetic dynamometer[2], photogrammetry[11], inclinometer, fleximeter, electrogoniometer and universal goniometer[13]) and an ideal protocol to measure the ROM.

However, despite the diversity of instruments for measurement of the ROM, the most often used procedure has been the goniometry[15,16], since it is easy to be used, non-invasive and of low cost[15], having both reliability and validity considered as being regular[15,16], strong[2,10,17], and very strong[18], depending on the movement analyzed.

For movements of inversion and eversion of the ankle, in the few studies conducted using healthy individuals, the measures have been proving themselves highly variable, presenting intraclass correlation coefficients (ICC) from low to moderate intra-rater reliability, and of moderate inter-rater reliability[19].

Besides that, due to the fact the physical conformation of the universal goniometer (UG) itself does not adapt well to the anatomy of the foot and because it cannot take two or three-dimensional measures, once the movements of inversion (plantar flexion, adduction and supination) and eversion (dorsiflexion, abduction and pronation)[19-21] of the ankle combine other ones in the sagittal, transverse and frontal planes[20,21], the hypothesis of this study was that the reliability of measures could improve with the use of a podalic arthrometer (PA),

due to its Best adaptation resulting from the coupling of its support base to the sole of the foot.

Given the above, this study aimed at evaluating the reliability of intra and inter-raters and interinstruments (UG *versus* PA) of active ROM of ankle eversion and inversion, in healthy individuals.

METHODOLOGY

Design of the study and sample characteristics

In order to carry out this cross-sectional clinical Trial, we selected, by convenience, among the students of the courses of Physical Therapy and Physical Education of the *Universidade Federal da Paraíba* (UFPB), 100 healthy individuals, who would meet the following inclusion criteria: be aged between 18 and 25 years old; body mass index (BMI) classified as eutrophic (18.5 to 24.99 kg/m^2) and not presenting alterations or osteomioarticular injuries which would promote inversion and evertion ROM limitations of the ankles.

The size of the sample was estimated through a pilot study, which determined the necessary number of participants (www.lee.dante.br). The criterion was to suit a difference of three degrees between assessers, measures and instruments and, therefore, a total of 100 individuals was necessary in order to achieve a test power of 85%, considering a significance level of 5%.

The individuals were informed on the objective of the study and signed a informed consent form, according to the resolution 466/2012 of the *Conselho Nacional de Saúde*, agreeing to their participation in the investigation, after the approval of the Research and Ethics Committee on Human Beings of the *Centro de Ciências da Saúde* of the UFPB, protocol No. 013/2013 and CAAE 12074612.6.0000.5188.

Procedures

Before the measures, the individuals were subjected to a simplified clinical evaluation, consisting of a muscle strength test (MST), ROM and kinesthesia, in order to detect some abnormalities which would compromise the results of the research.

In order to measure the ROM of the inversion and eversion movements of the ankle, we used a UG (Carci® – Brasil), medium sized, plastic, with two-degree measure scale, forming a 360º circumference (Figure 1A), and a PA (wooden prototype), consisting of two overlapping perpendicular rectangles. The horizontal triangle had an attached protractor in its center, forming a semi-circumference (180º), moving clockwise and counterclockwise, while the vertical one would support the foot (Figure 1B).

At the time of the measures, the evaluator who carried out the measurement could not take the reading, since the viewing place of the measurement (in degrees) of both instruments (UG and PA) was, purposely, covered with a cardboard, in order not to influence the subsequent measures. After receiving the instruments by the hands of the first assesser, the second one would lift the cardboard and register the reached angle, without the first one knowing the value taken. Up next, the second evaluator would also close the viewing measurement display and would hand in the goniometer to a third evaluator so they would register the measurement, without the first or the second one knowing the measure (shielded study)).

The inversion and eversion ROM of the ankle were performed by three evaluators (Ev1, Ev2 and Ev3) with

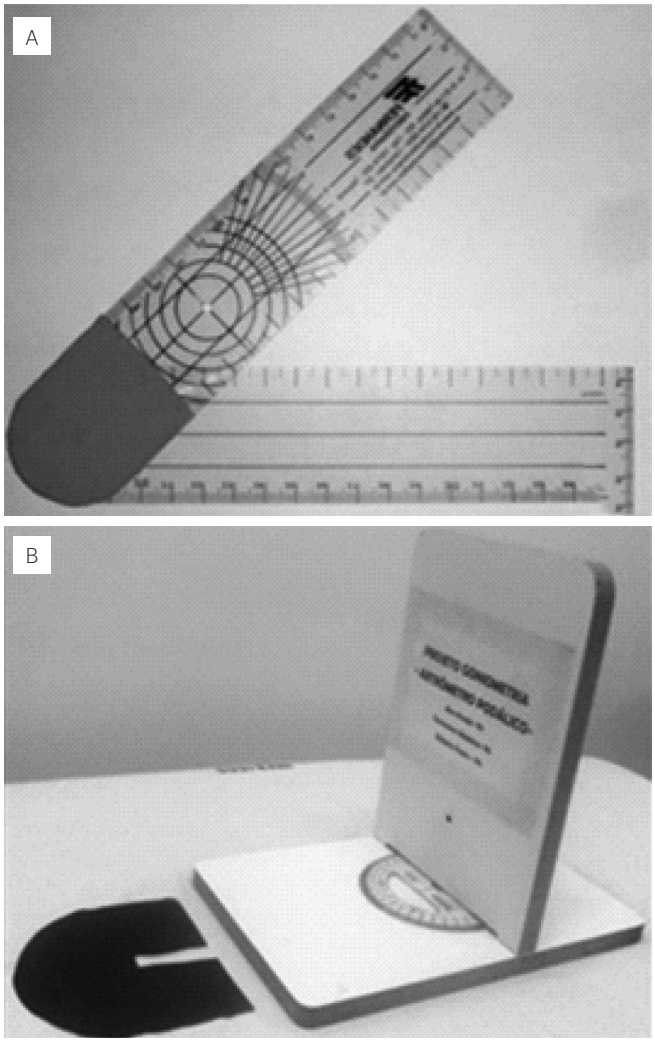

Figure 1. Universal goniometer (A) and podalic arthrometer (B)

varied practical experience (Ev1>two years; Ev2>one year; Ev3=six months) in the use of the UG, however, as for the applying of PA, all of them had the same experience, for many of them have used it after a familiarization period (15 training days), which was conducted under the supervision f a supervisor of the research.

For the measurement with the UG (Figures 2A and 2B) and the PA (Figures 2C and 2D), the individuals would stay in a supine position with the lower limbs extended on the examining table. In the measurement of inversion, the UG was positioned as the pivot to the side of the lateral border of the head of the fifth metatarsal, with a mobile arm of the line of the transverse arch of the foot (between the heads from the fist to the fifth metatarsal) and a fixed arm, parallel to the longitudinal medium line of the fibula. For the eversion measurement, the pivot was positioned on the medial border of the head of the first metatarsal, mobile arm, as it was done in the inversion and, the fixed arm, parallel to the longitudinal medium line of the tibia.

Each evaluator performed three consecutive measures, from the same individual, extracting the average among them, and repeating the measurement seven days after the first one. In each one of them, the ROM measument was registered by another evaluator in order to avoid induction of results.

During the measures, the order of the evaluators and members (left or right) was randomized for each individual (www.randomization.com). In the revaluation, the sequence of the first evaluation was maintained in order to verify the intra-rater.

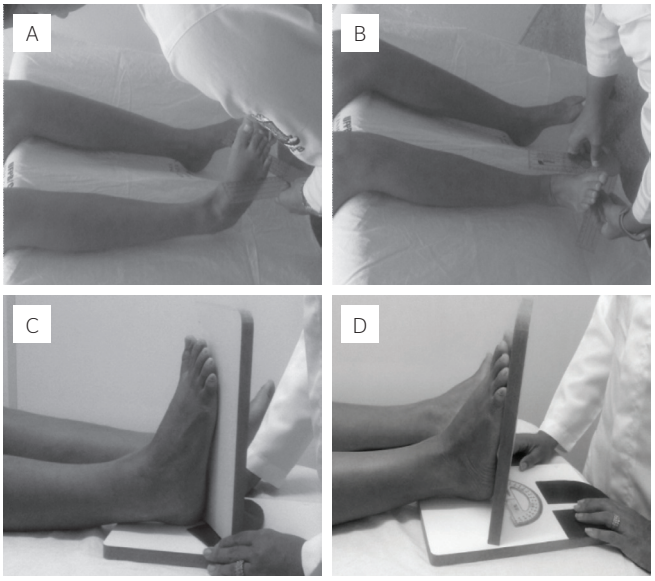

Figure 2. Inversion ande version measure of the ankle with universal goniometer (A and B) and with podalic arthrometer (C and D)

Data analysis

The statistical procedures were performed in the Statistical Package for the Social Sciences (SPSS) software, version 20.0. Initially, the normality of the data (Kolmogorov-Smirnov) and the homogeneity of the variances (Levene) were verified and, afterwards, the ICC was used in order to observe the reliability of the intra and inter-rater and interinstrument measures, besides the Pearson test to correlate the measures between UG and PA, considering a significance level of 5%.

For the analysis of the correlation coefficients, the following classification was considered: null=0.0; weak=0.01 to 0.3; regular=0.31 to 0.6; strong=0.61 to 0.9; very strong=0.91 to 0.99 and full=1.0[22].

RESULTS

From the 100 healthy individual who met the inclusion criteria of the study, 71 of them were women (21.39±2.53 years old; 56.30±8.31 kg; 1.62±0.06 m; and BMI: 21.38±3.01 kg/m^2) and 29 of them were men (21.14±2.68 years old; 70.45±9.72 kg; 1.74±0.06 m; and BMI: 23.15±3.08 kg/m^2).

According to Table 1, very strong and significant correlations were found (ICC 0.91≥0.99; p<0.001), both for the UG and the PA in three measures of ankle inversion and eversion, conducted by each one of the evaluators.

As for the inter-rater ROM (Table 2), there were strong correlations (ICC 0.61–0.9; p<0.01) for all movements, for both the first and the second measures, especially when measured with the PA, reaching higher coefficients (>0.8) than the UG (<0.8).

As for the correlation between the measures of the UG and the PA (Table 3), the Pearson test proved to be regular and significant (0.31≥r≤0.6; p<0.01) for all the evaluators, for both the first and the second evaluation (after seven days), except for the inversion movement in the second evaluation, measured by the second evaluator, which obtained a weak, though significant, correlation (r=0.255; p=0.01).

DISCUSSION

When analyzing the reliability of the measures, intra and inter-ratters and interinstruments (UG *versus* PA) of the active ROM of eversion and inversion of the

Table 1. Intra-class, intra-rater, inversion and eversion range of movement of the ankle correlation coefficients

Measures/evaluators	Inversion UG		Inversion PA		Eversion UG		Eversion PA	
	ICC*	p-value	ICC*	p-value	ICC*	p-value	ICC*	p-value
First measure								
Evaluator 1	0.941	<0.01	0.924	<0.01	0.976	<0.01	0.930	<0.01
Evaluator 2	0.954	<0.01	0.954	<0.01	0.944	<0.01	0.939	<0.01
Evaluator 3	0.954	<0.01	0.961	<0.01	0.952	<0.01	0.946	<0.01
Second measure								
Evaluator 1	0.962	<0.01	0.927	<0.01	0.965	<0.01	0.928	<0.01
Evaluator 2	0.957	<0.01	0.953	<0.01	0.935	<0.01	0.929	<0.01
Evaluator 3	0.949	<0.01	0.964	<0.01	0.948	<0.01	0.948	<0.01

ICC: intraclass correlation coefficient; UG: universal goniometer; PA: podalic arthrometer; *Crombach's alpha

Table 2. Intraclass, inter-rater, inversion and eversion range of movement of the ankle correlation coefficients

Measures/evaluators	Inversion UG		Inversion PA		Eversion UG		Eversion PA	
	ICC*	p-value	ICC*	p-value	ICC*	p-value	ICC*	p-value
Measure 1	0.706	0.001	0.834	0.001	0.734	0.001	0.811	0.001
Measure 2	0.688	0.001	0.838	0.001	0.724	0.001	0.813	0.001

ICC: intraclass correlation coefficient; UG: universal goniometer; PA: podalic arthrometer; *Crombach's alpha

Table 3. Interinstrument correlation measures (universal goniometer *versus* podalic arthrometer) of the inversion and eversion movements of the ankle

Movements	Evaluator 1		Evaluator 2		Evaluator 3	
	r	p-value	r	p-value	r	p-value
First evaluation						
Inversion	0.430	0.0001	0.307	0.002	0.418	0.0001
Eversion	0.388	0.0001	0.523	0.0001	0.327	0.0001
Second evaluation						
Inversion	0.478	0.0001	0.255	0.010	0.436	0.001
Eversion	0.342	0.0001	0.404	0.0001	0.332	0.001

UG: universal goniometer; PA: podalic arthrometer; r: Pearson's correlation coefficient

ankle, in healthy individuals, the present study found a ICC (very strong) in the intra-rater comparison, for both the UG and the PA, whether intra or inter-evaluation sessions, corroborating the study by Menadue et al.[19], in which, though a different methodology was used (goniometer positioned in the anteroinferior face of the leg, with the pivot on the medium point between the malleoli, the fixed arm followed by the medium line of the leg and the mobile one, on the anterior surface of the second metatarsal), also found similar results for the respective movements.

Besides that, confronting the results of the present study to the findings of Kovaleski et al.[23], who observed a strong intra-rater correlation (ICC=0.82), even having performed the study with corpses and having made use of an instrument (optoelectronic arthrometer) of higher accuracy than the UG and the PA, in which the evaluator does not interfere in the results, this study presented higher reliability (ICC>0.91), in both the analyzed instruments (UG and PA).

A little below the ICC achieved by the present study, Elveru et al.[24], who also analyzed the movements of inversion and eversion of the ankle, using the UG, found strong correlations, intra and intersessions of measures, applying the same time of interval between them (seven days). However, as they evaluated individuals with neurological and orthopedic disorders, the highest coefficient was in the inversion movement of individuals with orthopedic disorders (ICC=0.74) over the eversion of those who had neurological disorders with less reliability (ICC=0.65).

Also in this sense, Menadue et al.[19], however, evaluating the inversion and eversion active ROM of 30 healthy individuals, as Elveru et al.[24], who also found strong reliability for the inversion movement and from regular to strong for the eversion one, within the same session and in a space of 7 to 14 days between the first and the second evaluations.

The strong ICC, inter-raters, found in two measure sessions, for the two analyzed movements (inversion and eversion), for both the UG and the PA, is consistent with the studies by Menadue et al.[19] and Kovaleski et al.[23], although this study presents higher values than the ones obtained by the authors mentioned. This means that, for the evaluated moments, with the respective instruments, the time of experience of the evaluator, specially for the UG, did not influence the results of the measures.

On the other hand, the inversion and eversion ICC using the PA are higher than the ones presented by the UG, demonstrating it presented more reliable measures for the movements studied, even when executed by three different evaluators. Therefore, this instrument (PA), in general , may be used in order to evaluate and monitor the evolution of disorders which cause ROM deficit of

inversion and/or eversion of the ankle in a more trustful way than the UG.

Probably, these high ICC values found within the same session, between the different sessions (first and second evaluations) and also between evaluators (Ev1, Ev2 and Ev3), is attributed to the smaller influence that the evaluator has on the PA, when compared to the UG, which is the rater-dependent instrument, even if these have a great use experience.

Besides the fact that the instruments do not perform three-dimensional measures inherent to the movements of inversion (plantar flexion + adduction + supination) and eversion (dorsiflexion + abduction + pronation)[19-21] of the ankle, the lack of studies on the reliability of these measures, in healthy individuals, made difficult the discussion of the results, once that almost all studies that measured the inversion and eversion of the ROM have been analyzing the effect of external supports in order to stabilize the ankle[25] and the functional instability[26,27].

CONCLUSION

According to the results of this study, the instruments used to measure the inversion and eversion of the ankle (UG and PA) presented high reliability, even in different evaluation sessions (seven-day interval between them). Therefore, they may be used in Physical Therapy practices, regardless the experience of the evaluator, specially the PA, due to having demonstrated higher reliability coefficient in relation to the UG, probably, because of the lesser influence the evaluator has over it during the measure.

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