ISSN 0008-3194 (p)/ISSN 1715-6181 (e)/2017/121–127/$2.00/©JCCA 2017

Intra-examiner reliability of measurements of ankle range of motion using a modified inclinometer: a pilot study

Patricia Tavares, BSc, DC, FCCOS(C)[1]
Victoria Landsman, BSc, MA, PhD[2,3]
Leslie Wiltshire, BSc, DC[1]

A modified inclinometer was designed for measuring total ankle range of motion (ROM) in the standing position for a large future study. The purpose of this pilot study was to assess the intra-examiner reliability of this new device in order to see if the examiner would be able to produce equally reliable measurements with this instrument as with a routinely used goniometer.

Nineteen young healthy individuals took part in the pilot. The same examiner took the ROM measurements using both devices twice on the same day and one further time 2 or 3 days later. Test-retest reliability was measured using the intraclass correlation coefficient (ICC). The ICC values were 0.86 (95% CI=[0.67; 0.94]) and 0.83 (95% CI=[0.61; 0.93]) for the measurements taken with the goniometer on the same day and for those

On a conçu un inclinomètre modifié pour mesurer l'amplitude du mouvement (ADM) totale de la cheville en position debout pour une grande étude à venir. Cette étude pilote a pour objectif d'évaluer la fiabilité des intra-examinateurs vis-à-vis de ce nouveau dispositif afin de constater si l'examinateur serait en mesure de produire des mesures d'une fiabilité équivalente avec cet instrument par rapport au goniomètre couramment utilisé.

Dix-neuf jeunes personnes en santé ont participé à l'étude pilote. Le même examinateur a pris des mesures de l'ADM avec les deux dispositifs à deux reprises le même jour et une autre fois deux ou trois jours plus tard. On a mesuré la fiabilité de test-retest au moyen du coefficient de corrélation intraclasse (CCI). Les valeurs de CCI étaient de 0,86 (IC à 95 %=[0,67; 0,94]) et de 0,83 (IC de 95 %=[0,61; 0,93]) pour les mesures prises avec le goniomètre le même jour et les mesures prises lors de deux jours différents. Les

[1] Canadian Memorial Chiropractic College
[2] Institute for Work and Health
[3] University of Toronto, Dalla Lana School of Public Health, Department of Biostatistics

Corresponding author:
Patricia Tavares
Canadian Memorial Chiropractic College, 6100 Leslie Street, Toronto, ON M2H 3J1
e-mail: ptavares@cmcc.ca
Tel: 416-482-2340

The authors do not have any conflicts of interest to declare with regard to the preparation of this manuscript.
Financial support for this study was received from the Canadian Memorial Chiropractic College research department to cover equipment costs.

on two different days. The corresponding values for the modified inclinometer were 0.88 (95% CI=[0.72;0.95]) and 0.81 (95% CI=[0.57; 0.92]). Both instruments were found to have very good test-retest reliability.

(JCCA. 2017;61(2):121-127)

KEY WORDS: ankle, range of motion, pilot study, reliability, inclinometer

valeurs correspondantes pour l'inclinomètre modifié étaient de 0,88 (IC de 95 %=[0,72;0,95]) et de 0,81 (IC de 95 %=[0,57; 0,92]). On a constaté une très bonne fiabilité de test-retest avec les deux instruments.

(JCCA. 2017;61(2):121-127)

MOTS CLÉS : cheville, amplitude du mouvement, étude pilote, fiabilité, inclinomètre, chiropratique

Introduction

Ankle motion is required for humans to walk, run, sit down, climb, etc. A limitation in range therefore may affect quality of life.[1] Reductions in ankle range of motion (ROM) have been associated with co-morbid conditions such as venous ulcers. This association has been established in populations with high socioeconomic status[2,3] where the prevalence of venous ulcers is approximately 1% according to Fowkes FG *et al*.[4] . It is estimated that in Western countries 3 billion dollars is spent annually on the care of venous ulcers.[1] Neither a similar association nor prevalence has been established in a socioeconomically disadvantaged population where the economic burden of venous ulcer care would likely be significant.

We, the authors, plan to assess patients attending mobile chiropractic clinics across the Dominican Republic with the intention of investigating the association between venous disease and venous ulcers and ankle ROM in a socioeconomically disadvantaged population. It is expected that such a study would require a large number of ROM measurements to be taken in a short amount of time, in field conditions with various practical obstacles, in which traditional methods of measuring ankle ROM are not feasible. As a result a sturdy measurement tool would be required.

Goniometers are traditionally used to determine ROM of the ankle joint.[5] Goniometers are considered valid and reliable clinical tools for assessing range of motion of joints of the extremities.[6] A typical goniometric measurement of the ankle is made with the patient's leg supine on the treatment table and the fulcrum at the lateral malleolus whilst maintaining the bottom rod of the goniometer parallel with the tibia and fibula. This procedure requires skill on the part of the examiner and visual estimation of the same position of the goniometer arms at the same starting position at each successive measurement.[7] Measuring ROM with a standard plastic goniometer does not control the patient's ability to flex or extend the toes or control for the subtalar range of motion and its influence on ankle ROM. Belczak *et al*.[8] used a goniometer with a plantar support to eliminate the influence on ankle ROM of the other articulations of the foot on ankle ROM. Despite the assumption that the instrument may have been cumbersome to use in the field, the authors were unable to acquire it for testing.

More recently Thornton *et al*.[9] introduced a digital goniometer as an inexpensive, reliable and valid method of measuring functional ROM of the ankle, with the patient's foot on the floor. Although the results are interesting and promising, the proposed measurement methodology would have proved challenging in the conditions that were expected to be seen in the Dominican study. There, clinical conditions were expected to vary from day to day, with uncertain floor surfaces ranging from concrete to dirt. Moreover, the results of this study were not available at the time of the authors' study.

There are a variety of studies that use inclinometers to measure ankle ROM. According to Gerhardt *et al*.[7], inclinometers "read angle position relative to gravity or to a set neutral -0- position". Inclinometers for measuring ankle ROM, specifically ankle dorsiflexion[10] have shown to be reliable, and functional plantarflexion has been shown to be best quantified using an inclinometer on the dorsum of the foot in modern dancers[11]. To the best of their knowledge, the authors are not aware of another published study that established the reliability and validity of the full ROM of the ankle joint using an inclinometer.

A regular inclinometer does not control for subtalar

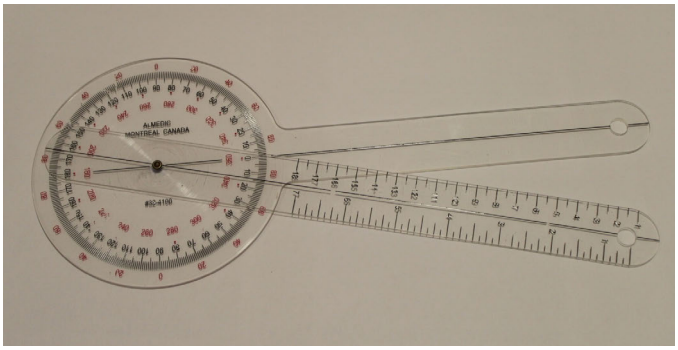

Figure 1.
Goniometer

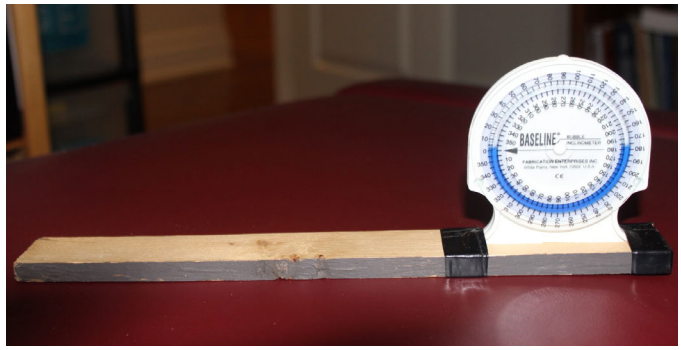

Figure 2.
Modified inclinometer

joint contribution to ankle ROM even with an extension arm as described by Gerhardt *et al*.[7] The extension arm described by Gerhardt was rather narrow in width, and would not allow a broad contact with the foot, which would reduce the subtalar contribution.[12] For this purpose, the authors designed a device with a wider plantar support to help to control the amount of toe and foot contribution to the ankle ROM. Furthermore the device needed be robust enough for repeated use on many participants. A detailed description of the modified inclinometer is provided in Methods and Materials.

Since the new device is a modified version of an existing inclinometer with an extended arm, we aimed to assess the intra-examiner reliability of the device. Secondarily we wanted to determine if the intra-examiner reliability of this new device was of a similar magnitude to that of a standard goniometer.

Methods

Ethical approval for this study was obtained from the Office of Research Administration of the Canadian Memorial Chiropractic College (CMCC). The REB certificate number was 1303X05.

Study participants

Participants were fourth year interns from the Canadian Memorial Chiropractic College. Participants were excluded if they had suffered an injury to the low back or lower extremity, including the ankle, within the last week. A recent low back injury may have hindered participants from sitting comfortably and dorsiflexing the ankle in one of the required positions, ie. sitting with a straight leg on the table as part of the goniometer measurements, as will be described.

Nineteen participants, seven males and twelve females, volunteered and were eligible to participate. They represent a homogenuous group of young generally fit individuals, of approximately the same age. Participants were asked to sign consent forms before participating. Participants were asked to maintain their usual level of activity during the entire duration of the study to eliminate bias in consecutive ROM measurements due to injury.

Instruments

Goniometer

The goniometer used was a usual plastic type 12 inch goniometer by Almedic from Montreal Canada #32-4 (see Figure 1).

Modified inclinometer

The new device consisted of a Baseline® bubble inclinometer made by Fabrication Enterprises Inc. attached to a long wooden stick designed by authors PT and LW (hereafter, a modified inclinometer). A device used by both Gerhardt[4] and Lea *et al*.[13]. was the original concept for this new apparatus. The apparatus consisted of a straight edge wood base 30 cm long, 3.8 cm wide and 0.95 cm thick. This was cut level, and thick enough not to distort while using the device for multiple measurements. A notch was cut into one end to hold the inclinometer, 8.3 cm long and 0.79 cm wide. The inclinometer was secured to the straight edge, level to the bottom (See Figure 2).

Participant Position and Procedure

Goniometer

The participant was seated with the right leg supine, knee straight, on a chiropractic table, and the other leg off the table. The goniometer's pivot was centered over the ankle (lateral malleolus), and one arm paralleled the fibula and tibia. The other arm followed a line parallel to the 5th metatarsal. The patient was asked to actively dorsiflex and plantar flex the ankle from a starting position with the foot relaxed (considered the zero neutral position) with angle measurements taken at each point of dorsiflexion and plantar flexion. The participant was asked to not dorsiflex or plantar flex the toes if possible. The neutral starting positon was returned to after dorsiflexion before commencing plantarflexion. Total ROM was measured as the sum of these two individual measurements. The test was repeated with the knee flexed to 45 degrees with a pillow under the supine knee. The average of the two total ROMs, one with the knee straight and one with the knee bent,was used to calculate the final value for the ROM using the goniometer[5].

Modified Inclinometer

The participant was in a standing position with the right knee on a chiropractic table, a modified position from that of Gerhardt's[7] method. The bent leg was positioned such that 50% of the lower part of the leg was on the surface of the table and 50% of the leg was off the table. The participant was asked to weight bear with the standing leg, not with the bent leg. The wooden arm was placed on the foot, with the foot in the most relaxed position possible. The inclinometer was placed at the heel so that the foot and toes made full contact with the wooden base. The contact was maintained in an effort to reduce the subtalar movement that might alter the ankle ROM.[12] The inclinometer was turned to establish this relaxed position as the zero degree position. The examiner held the bar along the base of the foot, and from the established zero degree position the participant moved the foot into maximum dorsiflexion without using the toes as he/she had been instructed to do. The angle of dorsiflexion was measured. The foot was then moved into the relaxed position again and the inclinometer was reset to zero. The participant was instructed to move into plantar flexion in the same way (See Figure 3). Total range of motion was then determined to be the addition of plantar flexion and dorsiflexion from the established zero position.

Measurements

In total, three ROM measurements were taken on each participant using the goniometer and the modified inclinometer each in turn following the procedures described above. Two measurements (Measurement 1 and Measurement 2) were taken on the same day, a few hours apart, and the third measurement (Measurement 3) was taken two or three days later, dependent on the interns' clinic schedules, to comply with standard intra-examiner design accepted in ROM measurement studies.[6]

All the ROM measurements were taken by the same examiner (PT), at the same location, in one of the clinic's treatment rooms on the clinic floor of the college with goniometer measurements always preceeding the modified inclinometer measurements by a few minutes. The interns appeared in random order for each of the three measurements. The measurements were recorded by an independent intern to ensure that the examiner (PT) was blinded to the previous measurement. To ensure the stability of the condition of the ankle of the volunteers, those who had suffered injures in the period between the second and the third measurements were excluded. In this study, none of the participants reported any injuries.

Figure 3.
Modified inclinometer measuring plantar flexion relative to a neutral relaxed position called zero.

Statistical Analysis

Means and standard deviations were calculated for each measurement of the ROM taken with a goniometer and a modified inclinometer.

Intraclass correlation coefficient (ICC) was used to assess the intra-examiner reliabilty. Based on classification defined by Fleiss and Shrout[14], we used ICC(2;1) as this measure is commonly used in the literature on test-retest reliability[15,16]. ICC(2;1) accounts for variability between the subjects and between the occasions on which the measurements were taken and can be calculated by fitting a two-way ANOVA model with subjects and occasions as factors. Two ICCs were obtained for each instrument to measure the reliability between Measurement 1 and Measurement 2, and between Measurement 1 and Measurement 3. The calculations were performed using the package *irr*[17] for R software[18].

Results

All the participants (n=19) were included in all three measurements. The mean and standard deviations of ankle ROM for each measurement are included in Table 1. ICC values for the goniometer were 0.86 (same day measurements) and 0.83 (measurements over different days). For the inclinometer these values were 0.88 and 0.81 respectively (Table 2). These values indicate very good reliability.[19]

Table 1.
Descriptive statistics for the ankle ROM using goniometer and modified inclinometer.

Test	Goniometer (mean [SD])	Modified inclinometer (mean [SD])
Measurement 1 (n=19)	59.08 [14.34]	69.26 [17.65]
Measurement 2 (n=19)	60.66 [16.45]	67.42 [14.95]
Measurement 3 (n=19)	60.26 [14.07]	70.68 [14.33]

Discussion

Currently the goniometer method used in this study is still the accepted way of measuring true range of motion of the ankle.[10] Goniometers, although commonly used to measure ankle ROM, are difficult to use when a high volume of measurements need to be taken in a short period of time in field conditions. The method using a digital goniometer, most recently proposed by Thornton *et al*.[9], seems to be a promising improvement to previous goniometry methods. However, its use required that the participants stand barefoot on the ground/floor, which would not have been prudent in a mobile clinic setting in a developing country where the ground surface would be less than ideal, and inconsistent on each day of measurement.

The intra-examiner reliability of the goniometer and modified inclinometer were obtained from the measurements of ROM taken on participants on the same day, as well as the measurements taken on two different days. In both cases, very good (above 0.80) ICCs were obtained, suggesting the two devices have comparably very good reliability.

Control for toe contribution, convenient patient position and ease of use combined with very good intra-examiner reliability make the modified inclinometer the device of choice for a large population study in which the measurements will be performed by the same examiner. However, it should be emphasized that clinimetric values of this new device have not been established yet and hence its use in clinical practice is not possible. Once an inter-rater reliability and validity of the modified inclin-

Table 2.
ICC(2;1) values and 95% confidence intervals (CI) obtained for goniometer and modified inclinometer.

Goniometer (ICC [95% CI])		Modified inclinometer (ICC [95% CI])	
Measurement 1 – Measurement 2	Measurement 1 – Measurement 3	Measurement 1 – Measurement 2	Measurement 1 – Measurement 3
0.856 (0.665; 0.942)	0.828 (0.607; 0.930)	0.883 (0.722; 0.953)	0.811 (0.574; 0.923)

ometer is established in future studies, the modified inclinometer can potentially become the device of choice in a regular clinical practice when relative improvements in ankle range of motion is the key required measurement.

It is worth mentioning that the ROM measurements obtained using a goniometer were systematically smaller than the ROM measurements obtained using the modified inclinometer by approximately 10 degrees (Table 1). A similar finding was reported in another study which compared goniometer to inclinometer measurements of ankle dorsiflexion[11].

There are a few possible explanations for this finding. Likely, it is because the goniometer averaged the straight leg and the bent knee, and calf muscles with a straight leg limit ankle dorsiflexion. Baumbach *et al*.[20] found that knee flexion of 20 degrees is enough to eliminate the effect of the gastrocnemius muscle on dorsiflexion of the ankle.

The systematic discrepancy between the two measurements can also be explained, in part, because the inclinometer measurements were always done after the goniometer ones, and it is likely that repeated measurements increased the ROM values. It would be important to randomize the order of the measurements in future studies to eliminate possible bias due to repeated measurements.

Currently the bubble inclinometer used in this study did not have the ability to establish the vertical gravity -0- position[7] in order to determine the absolute values for dorsiflexion and plantar flexion separately. However this inclinometer allowed the measurement of the total ROM (total of dorsiflexion plus plantarflexion from a set neutral -0- position) which was what would be required for the larger study. Further modification of this inclinometer to include the establishment of a vertical gravity -0- position would be important for future validity studies.

Conclusion

This study found a very good intra-examiner reliability for the modified inclinometer. This inclinometer is a sturdy device that helps to control for toe contribution to the ankle ROM, and allows taking measurements in the standing rather than in the supine position as is tradionally done when using a goniometer.

These obvious advantages of the new device and very good intra-examiner reliability make it suitable for use in a large population-based study in the Dominican Republic involving approximately a thousand patients attending mobile chiropractic clinics.

References

1. Dix FP, Brooke R, McCollum CN. Venous disease is associated with an impaired range of ankle movement. Eur J Vasc Endoasc Surg. 2003;25:556-561.
2. Belczak C, Cavalheri G, de Godoy J, Caffaro R, Belczak S. Relação entre a mobilidade da articulação talocrural e a úlcera veosa. J Vasc Bras. 2007;6(2):149-155.
3. Fowkes FG, Evans CJ, Lee AJ. Prevalence and risk factors of chronic venous insufficiency. Angiology. 2001; 52 Suppl 1:S5-15.
4. Eberhardt R, Raffetto J. Chronic venous insufficiency. Circulation. 2005;111:2398-2409.
5. Cocchiarella L, Andersson GB. Guides to the evaluation of permanent impairment.5th. ed. United States of America: American Medical Association, 2001: 535.
6. Gajdosik R, Bohannon R. Clinical measurement of range of motion: Review of goniometry emphasizing reliability and validity. Phys Ther. 67(12): 1867-1872.
7. Gerhardt J, Cocchiarella L, Lea R. The practical guide to range of motion Assessment. United States of America: American Medical Association, 2002:94-95.
8. Belczak C, Cavalheri G, de Godoy J, Caffaro R, Belczak S. Relação entre a mobilidade da articulação talocrural e a úlcera veosa. J Vasc Bras. 2007; 6(2): 149-155.
9. Thornton J, Sabah S, Segaren N, Cullen N, Goldberg A. Validated method for measuring functional range of motion in patients with ankle arthritis. Foot Ankle Int. 2016:37(8): 868-873.
10. Konor M, Morton S, Eckerson JM, Grindstaff TL. Reliability of three measures of ankle dorsiflexion range of motion. Int J Sports Phys Ther. 2012; 7(3): 279-287.
11. Dickson D, Hollman-Gage K, Ojofeitimi S and Bronner S. Comparison of functional ankle motion measures in modern dancers. JDMS. 2012; 16(3): 116.
12. Weaver K, Price R, Czerniecki J, Sangeorzan B. Design and validation of an instrument package designed to increase the reliability of ankle range of motion measurements. J Rehabil Res Dev. 2001; 38(5): 471-475.
13. Lea R, Gerhardt J. Current concepts review. Range-of-motion measurements. J Bone Joint Surg Am. 1995; 77A(5): 784- 798.
14. Shrout P, Fleiss J. Intraclass correlations: uses in assessing rater reliability. Psychol Bull. 1979; 86(2): 420-428.
15. Hogg-Johnson, S. Differences in reported psychometric properties of the Neck Disability Index: patient population or choice of methods? Spine J. 2009, 9(10): 854-856.
16. Stratford, P.W. On "Test-retest reliability and minimal detectable change on balance …" Steffen T, Seney M. Phys Ther 2008; 88: 733-46. Phys Ther. 2008; 88: 888-90.
17. Matthias Gamer, Jim Lemon, Ian Fellows, and Puspendra

Singh (2012). irr: Various Coefficients of Interrater Reliability and Agreement. R package version 0.84. https://CRAN.R-project.org/package=irr
18. R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/
19. Fleiss J.L. Reliability of measurement. The design and analysis of clinical experiments. New York: John Wiley & Sons, 1986: 1-32.
20. Baumbach S, Brumann M, Binder J, Mutschler W, Regauer M, Polzer H. The influence of knee position on ankle dorsiflexion- a biometric study. BMC Musculoskelet Disord. 2014; 15: 246.