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RELIABILITY OF PHOTOGRAMMETRY IN RELATION TO GONIOMETRY FOR POSTURAL LOWER LIMB ASSESSMENT

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ABSTRACT

Background: Postural assessment and joint range-of-motion measurements are fundamental in diagnosing, planning and following up the evolution and results from physical therapy treatment. These can be done with the aid of goniometry – the most common method in physical therapy practice – and also, through technological advances, by means of photogrammetry. Objective: To investigate the parallel reliability of computerized photogrammetry, using two software tools (Corel Draw and SAPo), in relation to goniometry, in four angles of the lower limbs. Method: Twenty-six asymptomatic volunteers of both sexes, aged between 18 and 45 years, were studied. None of them had leg length discrepancy greater than 1 cm. The tibiotarsal angle (TT), knee flexion/extension angle (F/E), quadriceps angle (Q) and subtalar angle (S) were measured. The measurement was done first with a manual goniometer and then with digital photogrammetry by means of the Corel Draw v. 12 and SAPo v.0.63 software. Results: There were no statistical differences between the three evaluation methods for the TT (p= 0.9991), S (p= 0.2159) and F/E (p= 0.4027) angles. However, for the Q angle there was a significant difference between goniometry and the software used in photogrammetry (p= 0.0067), although there was no significant difference between two software tools (p= 0.9920). This showed that the photogrammetry results were not influenced by the software used. Conclusion: In these healthy young subjects, computerized photogrammetry showed good parallel reliability in comparison with goniometry, for all the angles evaluated except for the Q angle. Therefore, in physical therapy practice, caution is needed in using Q angle measurements coming from different postural assessment methods.

Key words: goniometry; photogrammetry; posture.

RESUMO

Confiabilidade da Fotogrametria em Relação a Goniometria para Avaliação Postural de Membros Inferiores

Contextualização: A avaliação postural bem como a mensuração da amplitude articular são instrumentos fundamentais para o diagnóstico, planejamento e acompanhamento da evolução e dos resultados de um tratamento fisioterapêutico. Elas podem ser realizadas tanto pela goniometria - método mais utilizado na clínica fisioterapêutica – como, com o avanço tecnológico, pela fotogrametria. Objetivos: Verificar a confiabilidade paralela da fotogrametria computadorizada, utilizando dois softwares, o Corel Draw e o SAPo, em relação à goniometria para quatro ângulos nos membros inferiores. Casuística e métodos: Foram estudados 26 voluntários de ambos os sexos, assintomáticos, com idade entre 18 e 45 anos, sem anisomelia de membros inferiores maior que 1 cm. Foram mensurados os ângulos tíbio-társico (TT), de flexo/extensão do joelho (flex/ext), ângulo Q (Q) e ângulo do retropé, inicialmente, com um goniômetro manual e, posteriormente, pela fotogrametria digital por meio dos softwares Corel Draw v. 12 e SAPo v.0.63. Resultados: Os ângulos TT (p= 0,9991), do retropé (p= 0,2159) e de flexo/extensão do joelho (p= 0,4027) não foram estatisticamente diferentes entre os 3 métodos de avaliação. Já o ângulo Q foi significativamente diferente entre a goniometria e os dois softwares usados na fotogrametria (p= 0,0067), embora os valores obtidos pelos mesmos não tenham diferido entre si (p= 0,9920), demonstrando que os resultados da fotogrametria não foram influenciados pelos softwares utilizados. Conclusão: Para os ângulos avaliados em sujeitos jovens assintomáticos, a fotogrametria computadorizada é confiável paralelamente à goniometria, exceto para o ângulo Q. Portanto, na clínica fisioterapêutica, deve-se ter cautela no uso de medidas de ângulo Q provenientes de diferentes métodos de avaliação postural.

Palavras-chave: goniometria; fotogrametria; postura.

INTRODUCTION

Human posture is the kinematic relationship between the positions of the body joints at a given moment. In an ideal skeletal alignment, the muscles, joints and skeletal structures are expected to be in a state of dynamical balance, generating a minimal amount of effort and overload, leading to an optimal efficiency of the locomotive system[1]. Both postural assessment and objective joint range-of-motion measurement are of fundamental importance to diagnosis, planning and follow-up of the evolution and results of physical therapy treatment[1,2]. Although it is widely accepted that a balanced posture is important for good functioning of the musculoskeletal structures, postural assessment is a complex phenomenon and difficult to measure[3]. According to Iunes et al.[3], this could explain why there are so few study results that can associate postural alterations to injuries or specific musculoskeletal dysfunctions. Therefore, it is important to establish trustworthy and reliable methods aimed at quantifying variables that aid postural assessment, contributing to an evidence-based development of physical therapy.

Manual goniometry is widely used in clinical physical therapy to assess range-of-motion[4-6]. For postural assessment, the goniometer can also be used to measure joint angles[4-7]. Some of the advantages of this methodology are the low-cost of the instrument and ease of measurement, which depends almost exclusively on the assessor's previous experience[4]. These advantages make manual goniometry very accessible to clinical physical therapy. As a measuring instrument for the upper and lower limb joints, the reliability of the universal goniometer is considered good to excellent, but for measuring the range-of-motion of the trunk, its reliability is low[8]. Studies have shown high reliability for measures of shoulder and knee range-of-motion, when compared to methods of visual estimation and radiography, respectively[9,10], and moderate reliability for ankle dorsiflexion, when compared to the reliability of the digital inclinometer[11]. High correlations were also found between goniometric and radiographic measures[10] and between goniometry and isokinetic dynamometry measures[12] for knee range-of-motion, as well as good to excellent reproducibility for shoulder range-of-motion measurements[9].

With the advent of technology, digital photogrammetry is now considered an alternative to quantitative assessment of asymmetries in the postural assessment, as it can be used for linear and angular measurements[3,13,14]. According to the American Society for Photogrammetry and Remote Sensing, photogrammetry is the art, science, and technology of obtaining reliable information on physical objects and their surroundings by recording, measuring and interpreting photographic images and radiant electromagnetic energy patterns, as well as other sources[3,14]. Photogrammetry allows the recording of subtle changes and the inter-relations between different parts of the human body that are difficult to measure or record by other means[13,15].

The use of photogrammetry may facilitate the quantification of the morphological variables related to posture, bringing more reliable data than the ones obtained through visual observation. This fact is important for the credibility of clinical physical therapy, as well as for the reliability of rehabilitation research[3].

Furthermore, the filing process in photogrammetry has the convenience of saving space as well as time accessing recorded files. Another advantage of digital photography is the possibility of conjugation with computerized measuring processes, resulting in computerized photogrammetry[16]. Therefore, computerized photogrammetry is the combination of digital photography and software such as Corel Draw[17-19], that allows the measurement of horizontal and vertical distances and angles for various ends, or others specifically developed for postural assessment such as SAPo (Software for Assessment of Posture), a nationally-funded free software developed with scientific basis, database, and web access[20, 21].

The measurement of the range-of-motion of joints and other parts of the body in relation to one another must be reliable and standardized, allowing not only the comparison of phases and the assessment of treatment effectiveness, but also the publication of results for the benefit of other professionals[2,16,22].

In a study by Iunes et al.[3], computerized photogrammetry in postural assessments presented acceptable inter- and intra-assessor reliability (intraclass correlation index [ICC] between 0.71 and 0.79) for most of the assessed angular measures, being therefore recommended for asymmetry and postural deviation assessments. However the repeatability of the method is low, and follow-up of pre- and post-treatment results may not be sufficiently reliable[3]. Zonnenberg et al.[23] found a high inter- and intra-assessor reliability for all the angular measures taken with photogrammetry but, as with Iunes et al.[3], the method's repeatability was low. In contrast, Braun and Amundson[24] found adequate reliability and repeatability for the postural assessment of the head and shoulders by means of photogrammetry. Other studies have also shown high reliability of photometric techniques for the assessment of the shoulder and trunk range-of-motion[25,26].

Rothstein[27] classifies the different kinds of intra-assessor, inter-assessor and parallel reliability. Parallel reliability compares the values or results obtained by different instruments or tests at the same time. It is used when the aim is to obtain alternative instruments, similar to the reference instrument. To analyze the parallel reliability of a new instrument, it must be compared to a reference instrument which has been previously tested and considered reliable[28,29]. Given that manual goniometry is the most common method in physical therapy practice with good to excellent reliability[2,8], it is considered the reference instrument to which new methods and instruments, such as computerized photogrammetry, may be compared.

In light of that, the objective of the present study was to verify the parallel reliability of computerized photogrammetry in relation to goniometry for four angles of the lower limbs, by means of two software tools: Corel Draw v. 12 and SAPo v. 0.63. In this sense, we endeavored to study the features of measurements that may contribute to the development of an evidence-based physical therapy assessment process.

METHODS

This study had a cross-sectional observational research design and was approved by the local Ethics Committee (protocol number 1237/05). Twenty-six volunteers of both genders (9 men and 17 women) were studied, with a total of 52 lower limbs. The inclusion criteria were asymptomatic individuals between 18 and 45 years of age. Exclusion criteria were significant postural asymmetries, leg length discrepancy (greater than 1 cm) and episodes of pain in the lower limbs and lower back during the previous three months. The subjects were asked to sign a free and informed consent, according to Resolution 196/96 of the National Health Council.

All subjects completed an initial questionnaire, including personal details (name, age, phone numbers, gender, and profession), and questions regarding the abovementioned exclusion criteria. The body mass and height of the subjects were measured.

The tibiotarsal angle (TT), knee flexion/extension angle (F/E), quadriceps angle (Q), and subtalar angle (S) were measured by the same assessor (Table 1) using manual goniometry[22] and digital photogrammetry[13]. For all goniometric and photogrammetric measures, the individual was in the stance position on a bench (20 cm high x 40 cm long x 40 cm wide) placed 15 cm from a wall with a posture evaluation grid. Two plumb lines hanged from the roof on each side of the positioning bench past the feet of the individual. An ethyl vinyl acetate (EVA) rectangle (7cm wide x 30cm long) was placed between the feet to maintain the position inter- and intra-subjects in all measurements.

To replicate the goniometry of clinical practice, measurements were taken without marking the anatomical points. This option may affect the study results but marking anatomical points for goniometric measurement would be a deviation from the normal use of the instrument.

Subjects wore bathing suits during both the goniometric and photogrammetric assessments. Goniometry was performed with the subject in the stance position. The first angle to be measured was the TT by placing the fulcrum of the goniometer on the lateral malleolus. The stationary arm was projected toward the tuberosity of the distal diaphysis of the fifth metatarsus, and the moving arm toward the head of the fibula. Next, the F/E angle of the knee was measured with the fulcrum on the head of the fibula, the stationary arm over the lateral surface of the thigh, projected toward the greater trochanter of the femur, and the moving arm over the fibula projected toward the lateral malleolus of the ankle. Both angles were measured first on the right lower limb and then on the left. After these procedures, the Q angle was measured by placing the fulcrum of the goniometer over the center of the patella, the stationary arm along the femur, projected toward the anterior superior iliac spine (ASIS), and the moving arm over the tibial tuberosity. Finally, the S angle was measured with the fulcrum of the goniometer over the midpoint between both malleoli, the stationary arm over the lower third of the tibia, and the moving arm aligned with the calcaneus.

After goniometry, subjects were photographed in a private, well-lit, heated room, with a non-reflexive background. Anatomical points were located and marked bilaterally with red self-adhesive tags (0.9cm in diameter) for subsequent angle calculation using the software. They were: center of the patella, tibial tuberosity and anterior superior iliac spine (ASIS) (anterior frontal plane); midpoint of the lower third of the leg, midpoint of the calcaneus,

Table 1. Description of the angles measured in goniometry and photogrammetry.

Angle	Fulcrum	Stationary arm	Moving arm
Tibiotarsal angle (TT)	Lateral malleolus	Toward the fifth metatarsal head	Toward the head of fibula
Knee Extension/ Flexion angle (F/E)	Head of fibula	Lateral thigh surface toward greater trochanter of femur	Along the fibula toward lateral malleolus
Q Angle *	Center of the patella	Along the femur toward the ASIS	Tibial tuberosity
Subtalar angle (S)	Midpoint between the two malleoli	Along the inferior third of the tibia	Aligned with the calcaneus

* the value considered was 180º subtracted from the angle measured by the goniometer.

midpoint between the malleoli (posterior frontal plane); tuberosity of the distal diaphysis of the fifth metatarsus, lateral malleolus, head of the fibula and greater trochanter of the femur (sagittal plane).

The subjects were photographed in the right and left sagittal, and anterior and posterior frontal planes with a 2 megapixel (1600 x 1200 pixel) digital camera parallel to the ground, at a distance of 3m from the bench and mounted on a level tripod 70 cm high (at knee height) (Figure 1). In the sagittal plane, the subject had the elbows flexed at 90º and, in the frontal plane, the arms were to the side of the body.

The photogrammetric calculation of the angles in question was performed by means of two software programs: Corel Draw v. 12 and SAPo v. 0.63. The marked anatomical points were used to measure the angles with the axes and vortices described in the goniometry (Table 1), except for the Q angle, measured directly with the extension of the line between the center of the patella and the tibial tuberosity, without the need to subtract it from 180º (Figure 2).

After collection, organization and verification of the data normality by means of the Shapiro-Wilks adherence test, we compared the calculated variables between the methods by using the ANOVA test for repeated measures (α= 0.06) and Scheffé's post hoc test. Pearson's correlation was also applied to the methods in order to verify the strength of the relationship between them. The Pearson correlation was considered significant when the p value was less than 0.05. The r values lower than 0.40 were considered low correlation; between 0.41 and 0.59, moderate; between 0.60 and 0.79, good, and above 0.80 high. The parallel reliability tends to be lower than the intra-assessor reliability and the instrument reliability as it involves measures from different devices, and usually with different scales[28]. In the present study, for example, the measuring scale of the goniometer and of Corel Draw was numeric, while SAPo's was decimal.

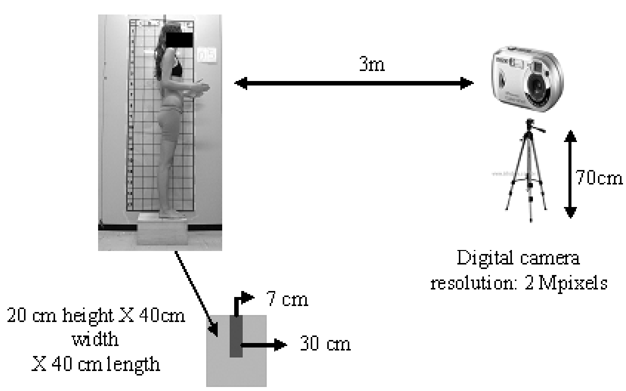

Figure 1. Digital photo standardization (description of camera resolution, distance between camera and subject, tripod height and dimensions of the wooden stool and the rectangular EVA device placed between the feet to standardize their position).

RESULTS

The 26 subjects (9 males and 17 females) presented mean age of 21.7 ± 4.9 years, mean body mass of 62.7 ± 13.8 kg and mean height of 168.1 ± 11.8 cm. The TT angle (p= 0.9991), S angle (p= 0.2159) and F/E angle (p= 0.4027) were not statistically different among the three assessment methods (Table 2). The Q angle was significantly different among goniometry and the two software programs used in photogrammetry (p= 0.0067) (Table 2), although the values obtained by Corel Draw and SAPo did not differ from one another (p= 0.9920), showing that the software used for all the assessed angles did not influence the photogrammetry results.

The TT angle presented significant correlation (p< 0.05) in all methods, with the correlation between goniometry and software near 50%, and of 85% between both photogrammetry software programs. The F/E angle presented significant correlation between goniometry and photogrammetry with Corel Draw, however a low, non-significant correlation was found between SAPo and goniometry, and between SAPo and Corel Draw. The Q angle presented good and significant correlation between Corel and goniometry, but not between goniometry and SAPo, and a high correlation between both programs. The S angle presented low, non-significant correlation between goniometry and the software programs. In contrast, both photogrammetry methods showed a high and significant correlation for this angle (Table 3).

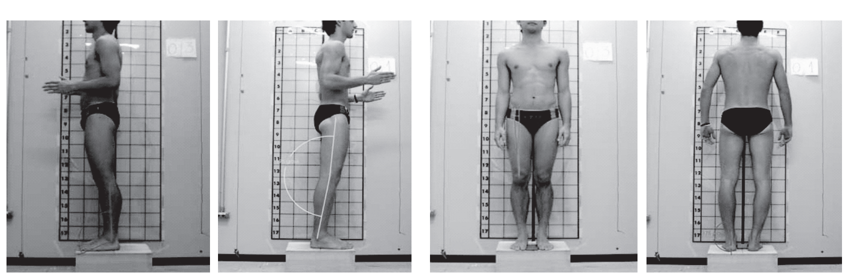

Figure 2. Illustration of the angle measurements using Corel Draw v. 12.

Table 2. Means, standard deviations of the angular variables measured with the three assessment methods, and p values.

	Goniometry	Corel Draw	SAPo	p
Tibiotarsal Angle (degrees)	112.3 ± 4.0	112.4 ± 3.6	112.4 ± 3.4	0.9991
Subtalar Angle (degrees)	7.1 ± 3.7	8.1 ± 4.5	8.1 ± 4.4	0.2159
Q Angle (degrees)	15.0 ± 5.6	13.1 ± 7.8	13.1 ± 7.8	0.0068 *
Knee Flexion/Extension angle (degrees)	184.0 ± 4.7	181.7 ± 4.1	181.6 ± 4.3	0.4027

* represents significant difference, $p< 0.05$.

Table 3. Pearson's Correlations among the three assessment methods, r and p values.

Variables	Comparisons 2 x 2	r	p	Correlation
Tibiotarsal Angle	Gonio/Corel	0.41	0.003	moderate
	Gonio/SAPo	0.47	0.001	moderate
	Corel/SAPo	0.85	0.000	high
Knee Flexion/Extension Angle	Gonio/Corel	0.48	0.000	moderate
	Gonio/SAPo	0.06	0.6721	low
	Corel/SAPo	0.04	0.7791	low
Q Angle	Gonio/Corel	0.65	0.0000	good
	Gonio/SAPo	0.06	0.6721	low
	Corel/SAPo	0.97	0.0000	high
Subtalar Angle	Gonio/Corel	-0.11	0.4682	low
	Gonio/SAPo	-0.09	0.5232	low
	Corel/SAPo	0.83	0.000	high

DISCUSSION

Based on these results, it was clear that goniometry and computerized photogrammetry with both software programs (Corel Draw and SAPo) were very similar for the TT, S and F/E angles. The exception was the Q angle, which was different for goniometry and photogrammetry, but similar for both programs used in the photogrammetric calculations.

Although the Q angle is widely used in clinical physical therapy, few studies have performed reliability tests of this measure[30]. It is believed that the unsatisfactory results found in the present study are due to the fact that, for this angle, anatomical reference points are distant from each other and their muscle mass and arrangement is such that hinders the positioning of the goniometer arms. Furthermore, the Q angle measure involves postures of more than one joint complex, including the pelvis, hip, femoral-patellar, and femoral-tibial complexes, adding up to almost a dozen of degrees of freedom. Therefore, postural alterations in each one of the degrees of freedom of these three joint complexes (pelvis, hip and knee) may alter the measure of the Q angle both in goniometry and photogrammetry.

This finding is in accordance with the studies that found a low intra- and inter-assessor reliability (ICC between 0.14 and 0.37) for the clinical measure of the Q angle, as well as a low correlation between the clinical and the radiographic measure of this angle[30]. In contrast, a study found ICC results over 0.80 for the intra-assessor reliability and above 0.60 for the inter-assessor reliability for the Q angle measure[31]. It is also argued that the lateralization of the patella can alter the Q angle measures, leading to lower values for this angle. In this case, it was proposed that the medial-lateral orientation of the patella be measured to improve the reliability and clinical applicability of this measure[32].

As for the other angles, the anatomical points are either close to the goniometer arms or on a plane on the human body, so that the arms do not need to contour anatomical irregularities. Thus, for the F/E angle, for example, the side of the thigh served as reference for the positioning of the goniometer arm, aligning it with the greater trochanter of the femur. These points can be positioned directly under a goniometer arm.

With regard to the Pearson correlations, both software programs used in photogrammetry had a high and significant correlation. This suggests that, proportionally, the measures vary in a similar fashion, are related to one another and are reliable in parallel terms. No studies were found in the literature comparing these two software programs in postural analysis for the assessed angles.

Between goniometry and Corel Draw photogrammetry, moderate and good correlations were found, with exception of the S angle, which was low.

Between goniometry and the SAPo photogrammetry, a low and non-significant correlation was verified. As previously described, the goniometry and the Corel Draw program scales are numeric, whereas the SAPo scale is decimal, yielding different results that may be expressed by these low correlations.

CONCLUSION

The study showed that, for the angles assessed in young asymptomatic individuals, computerized photogrammetry is reliable in parallel terms to goniometry, except for the Q angle. In addition to that, the measurements taken with photogrammetry, regardless of the software used, were similar and did not interfere in the assessments. Therefore, in clinical physical therapy, caution should be used with Q angle measurements derived from different methods of postural assessment.

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