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Original Article (short paper)

Intra-rater and Inter-instrument Reliability on Range of Movement of Active Knee Extension

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Abstract — The objective of the present study was to evaluate the reliability of intra-rater and inter-instrument measures during two flexibility programs. Fifty-three active and healthy males, aged between 18 and 28 years old, were randomly included in three groups: control (Cg, n = 18), static stretching (SSg, n = 17), and dynamic stretching (DSg, n = 18). All participants underwent measurements of their active range of knee extension using manual goniometry and computerized photogrammetry, measured in four separated assessments and analyzed using the SPSS, with α£5%. Both methodologies presented very strong intra-rater reliability(ICC: 0.91³0.99; P<0.001) at all four assessments in all the groups, and the instruments showed weak (r: 0.31–0.6) to strong(r: 0.61–0.9) correlation, in the Cg (P<0.05) and strong (r: 0.61–0.9) in the SSg and DSg (P<0.01),although without differences between groups, indicating that the measures are equally reliable, regardless of interventions.

Keywords: articular range of motion;evaluation; reproducibility of results

Introduction

Range of motion (ROM), an important parameter used in the assessment, planning and development of physical therapy treatment,makes it possible, besides identifying joint limitations, to assess quantitatively, through instruments, the efficiency of therapeutic programs[1,2]. For an instrument to be employed, it is necessary that it presents reproducibility and reliability to demonstrate consistency between successive measurements of the same variable in the same subject and the same conditions[3].

Among the methods most used to quantify ROM in physical therapy practice, manual goniometry, measured by the universal goniometer (UG), is considered the gold standard[4]. However, despite being inexpensive and easy to apply, this instrument is rater-dependent[5], and therefore, its use has shown conflicting results between studies[6-8]. However, other studies[3,9,10], showed "poor" to "excellent" reliability indices for the upper and lower limbs joints, respectively, although Aalto, Airaksinem, Harkonen, Arokoski[11] found low reliability in measurements of the knee joint.

More recently, following the technological evolution, the use of computerized photogrammetry has been featured in the measurement of ROM, through recording, measuring and interpreting photographic images[12] using software that allows measuring angles and horizontal and vertical distances for various purposes[3,14]. Even when compared to goniometry, this method has shown high consistency inter- and Intra-rater[14,15]; however, similar to the study by Iunes, Castro, Salgado, Moura, Oliveira, Bevilaqua-Grossi[16], the repeatability of the method is also low.

Even though the manual goniometer is an old method and widely used by physiotherapists in their daily lives mainly due to its ease of use, reliable and detailed assessments of patients are essential for the clinical success of a therapeutic program. Considering the existence of different instruments for measuring ROM, there is still a shortage of studies ratifying the use of computerized photogrammetry as an alternative to manual goniometry in the recording of joint measurements, specifically in the range of active knee extension. In addition, the photographic register during the physical examination can facilitate the identification of important joint deficits, not displayed at the time of physical therapy assessment.

Thus, the hypothesis of this study was that the measurement of active knee extension ROM by photogrammetry was as accurate and reliable as manual goniometry. Therefore, the aim of this study was to evaluate and inter-instrument reliability for the active ROM of knee extension after stretching programs in active and uninjured individuals.

Methods

The sample consisted of 53 active and healthy male students, recruited by convenience through electronic disclosure and personal contact at the Federal University of Rio Grande do Norte (UFRN) and randomly assigned (www.randomization.com) to three groups: 1) control (Cg, n = 18; 21.27 ± 2.8 years; 74.38 ± 9.2 kg; 1.76 ± 0.1 m; BMI: 23.94 ± 1 8 kg/m^2); 2) static stretching (SSg, n = 17; 23.07 ± 3.5 years; 68.07 ± 9.0 kg; 1.72 ± 0.1 m; BMI: 22.98 ± 2.7 kg/m^2); and 3) dynamic stretching (DSg, n = 18; 21.47 ± 3.0 years; 72.06 ± 8.2 kg; 1.74 ± 0.1 m; BMI: 23.68 ± 1.3 kg/m^2), as shown in Figure 1.

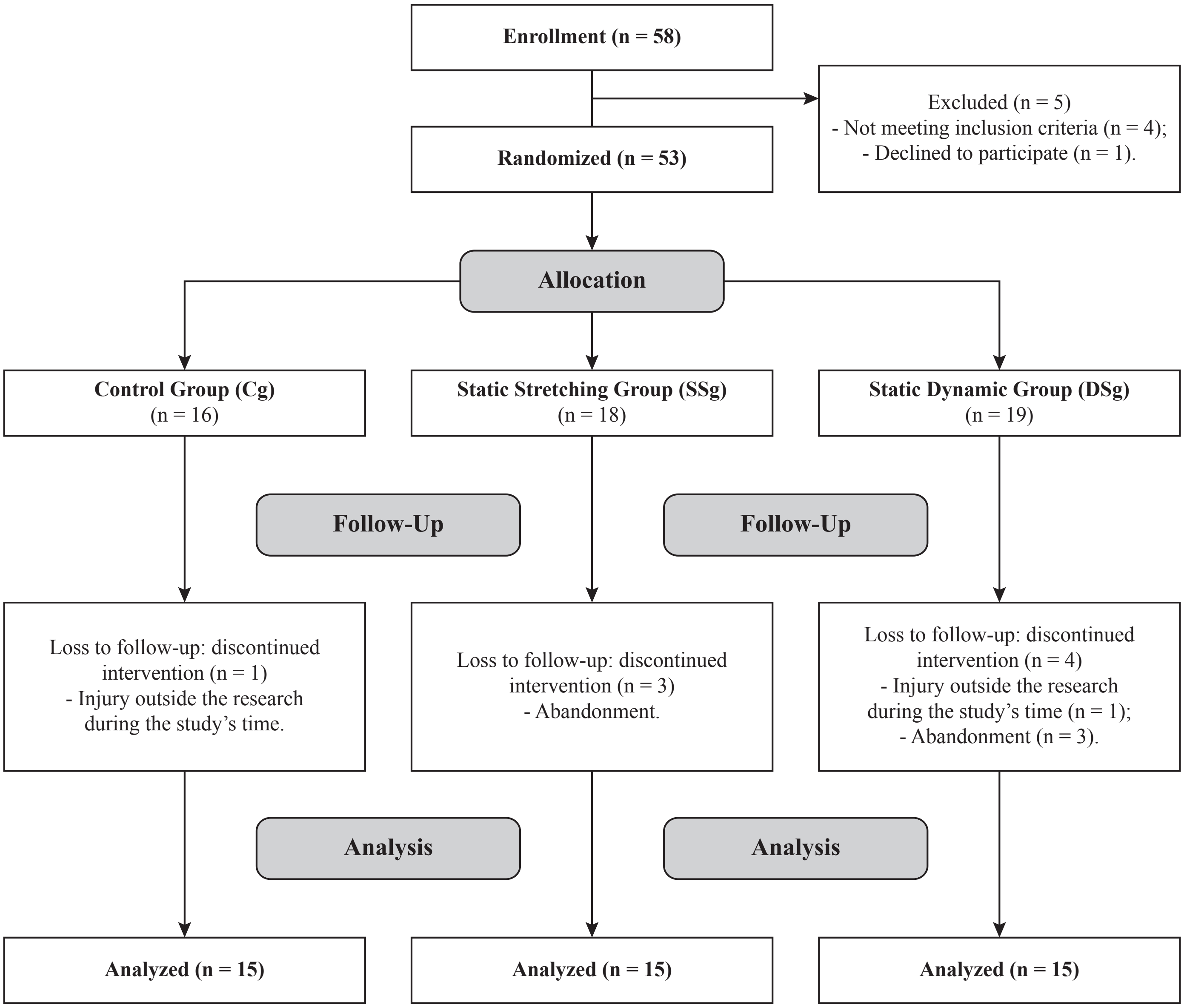

Figure 1. Study flowchart.

The inclusion criteria for the study were: 1) male; 2) aged between 18 and 28 years old; 3) normal weight, with body mass index (BMI) of 21–25 kg/m^2; 4) no history of injury, trauma or diseases in the lower limb in the last six months; 5) do not have health limitations, according to the Readiness Physical Activity Questionnaire –PAR-Q[17]; 6) practice physical activity (recreational, not competitive level) at least three times a week; 7) ROM limitation of at least 15° of active knee extension[18] in the assessed limb (considering 180°as full knee extension with hip positioned at 90° of flexion).

After the study was approved by the Research Ethics Committee of the Science and Health Center of the Federal University of Rio Grande do Norte (CEP/CCS/UFRN), under the protocol n. 1132671, Presentation Certificate for Ethics Appreciation (PCEA): 30168614.8.0000.5188, all subjects were instructed about the procedures and signed a consent form, according to the Resolution 466/2012 of the National Health Council (NHC) and Declaration of Helsinki.

Procedure and assessment measures

Active knee extension ROM measurements were carried out in four separate assessments, using universal goniometer (GU) and computerized photogrammetry. For the Cg, evaluations were performed with the same frequency of the intervention groups, however its participants did not perform the stretching techniques. The first researcher, who has expertise in this measurement technique, was responsible for the measurements and the second was responsible for recording the data.

For the groups that underwent the sessions of static and dynamic stretching (SSg and DSg), the first assessment (A1) was performed at least 48 hours before the first stretching session, while the other assessments, (A2, A3 and A4), were performed, respectively, immediately after the first session,tenth session and 48 hours after the third assessment.

G*Power 3.1.0 software was used for the sample calculation and all procedures were performed according to previous studies[19]. Based on a pilot study of nine volunteers, a power of 0.95 was adopted (level of significance = 5%, correction coefficient = 0.5, effect size = 0.25). An “n”= 15 volunteers for each group (“n” sample = 45) were calculated in order to provide a sample size with 95.5% statistical power.

Universal goniometry

A universal goniometer (Carci®, unit = degrees) was used, as well as an examination table and a wooden device, developed for positioning and fixating the subjects legs. This wooden device consists of two vertical bars fixed on the sides of the examination table and a horizontal bar used to connect the vertical bars together[20].

The subjects were positioned supine with their arms crossed on their chest, while the hip and knee of the non-dominant limb (NDL) were flexed at 90°, so that the anterior thigh remained supported on the horizontal crossbar, limiting hip flexion. A stabilization strap was used on the pelvis at the anterior superior iliac spines region (ASIS) and another fixed the dominant lower limb at the lower third of the thigh (Figure 2A). The subjects were then instructed to actively move their leg toward knee extension. The NDL was chosen because it is less skilled and more trainable than the dominant limb (DL). In order to identify limb dominance, the participants were asked which limb they prefer to use to kick a ball[21].

The assessment using the universal goniometer was “blind” and its pivot was covered with cardboard in order to not influence subsequent measurements[22]. The instrument was placed on the lateral side of the knee, with the axis coinciding with the lateral epicondyle of the femur, the fixed arm was aligned with the greater trochanter of the femur and the moving arm with the lateral malleolus. Each subject had their knee extension angle measured three times, in all assessments, and the register was taken by a second examiner.

Computerized photogrammetry

After goniometric assessment, the subjects remained in the same position for image-capturing, using a digital camera (Canon® G7x- Japan) that was mounted on a tripod, positioned 2.5 meters away from the examination table and aligned with each subject’s knee joint.

Four passive markers were set on the following anatomical reference points: greater trochanter of the femur (GTF); lateral epicondyle of the femur (LEF); fibular head (FH); and lateral malleolus (LM). *Image JSoftware* (Bethesda, MA, USA) was used to analyze the images, which generate the active knee extension angle by matching the GTF lines with the LEF, and the FH lines with the LM (range; Gama, Dantas, Souza[23]), as shown in Figure 2B. Only one image was captured, however, it was analyzed three times by the first examiner and registered on a spreadsheet by a second examiner to avoid any induction of results.

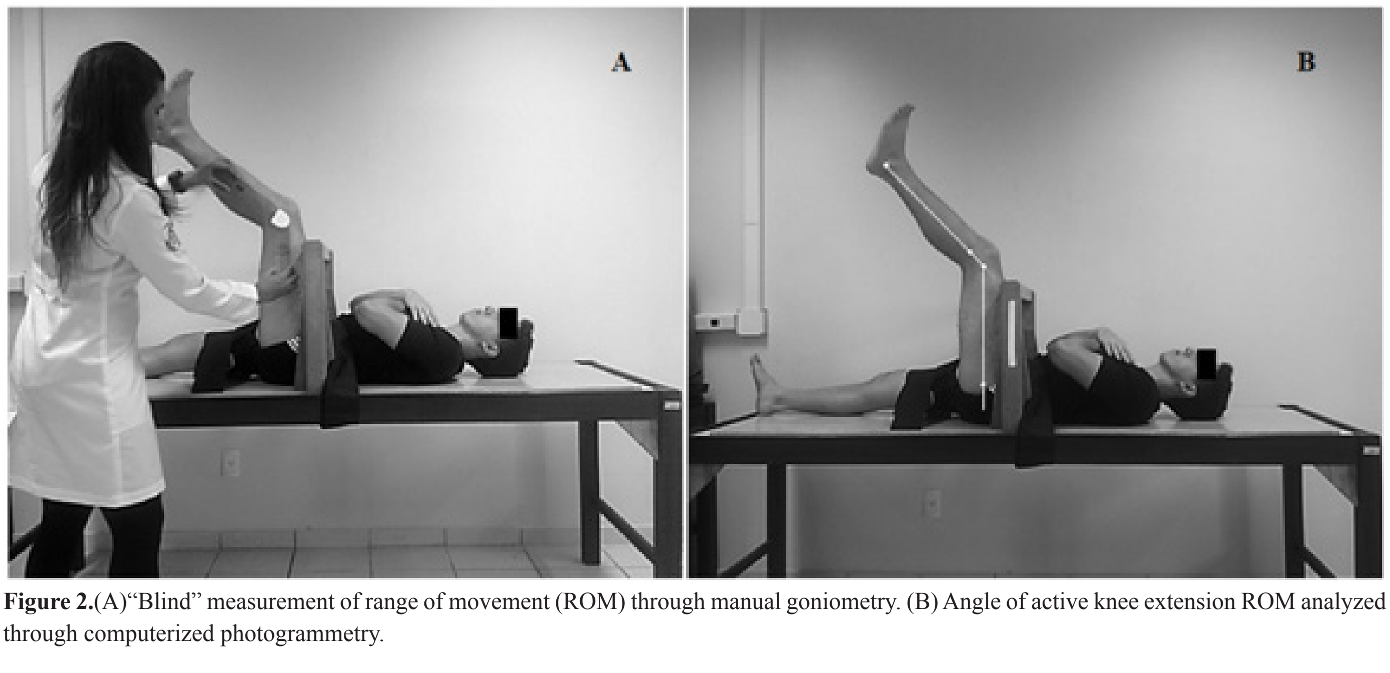

Figure 2.(A)“Blind” measurement of range of movement (ROM) through manual goniometry. (B) Angle of active knee extension ROM analyzed through computerized photogrammetry.

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences software (SPSS 20.0). Initially, the normality of data (Shapiro-Wilk test) and homogeneity of variances (Levene test) were observed, followed by the intra-class correlation coefficient [$ICC_{1,1}$; $Model_1$ (one way) and $Forms_1$ (single measures),respectively]in the comparison between the ROM measures in all analyzed groups (control, static and dynamic), the Pearson test to analyze the correlation between instruments (Goniometry × Photogrammetry) and the ANOVA to compare the difference inter-group and inter-instrument, adopting a significance level of 5% in all comparisons.

For Pearson correlation coefficient (r) analysis, the following classification was considered[9]: null = 0.0; very weak = 0.01–0.3; weak= 0.31–0.6; strong = 0.61–0.9; very strong 0.91–0.99; and full = 1.0.

Results

According to Table 1, the results of intra-rater intra-class correlation coefficients ($ICC_{1,1}$) found in the three measurements performed during the active knee extension movement showed very strong reliabilities ($ICC_{1,1}$: $0.91^{3}0.99$; P<0.001)in the measurements with UG, in each one of the four assessments, in all groups (control, static and dynamic), except for the A4_SSg, which had a strong reliability ($ICC_{1,1}$: 0.815; P<0.001).

Table 1 Intra-rater intra-class correlation coefficient ($ICC_{1,1}$) values for active knee extension range of motion with manual goniometry

Assessment/groups	Measurements				
	1	2	3	P-value	$ICC_{1,1}$
A1_Cg	138.9±7.8	139.9±8.0	140.4±7.8	0.0001	0.974
A2_Cg	136.2±7.9	137.7±7.4	136.8±9.0	0.0001	0.967
A3_Cg	139.3±9.8	139.5±9.2	138.9±9.6	0.0001	0.981
A4_Cg	138.4±9.4	139.2±9.7	139.4±10.8	0.0001	0.973
A1_SSg	135.9±11.5	137.1±12.0	136.9±10.7	0.0001	0.981
A2_SSg	136.2±14.6	136.4±14.4	139.4±14.1	0.0001	0.989
A3_SSg	140.4±13.8	140.9±12.9	140.9±12.6	0.0001	0.986
A4_SSg	138.0±13.9	132.9±30.2	140.0±14.5	0.0001	0.815
A1_DSg	135.6±9.8	136.4±10.1	135.9±10.1	0.0001	0.975
A2_DSg	136.5±11.4	136.4±10.8	136.4±10.2	0.0001	0.976
A3_DSg	138.9±8.9	140.8±8.2	140.8±7.7	0.0001	0.959
A4_DSg	139.1±9.0	138.9±10.4	140.4±10.5	0.0001	0.990

Measurements of groups expressed in mean±SD.

Legend: A1 = assessment 1; A2 = assessment 2; A3 = assessment 3; A4 = assessment 4; Cg = control group; SSg = static stretching group; DSg= dynamic stretching group.

Note: $ICC_{1,1}$ = $Model_1$ (*one way*) and $Forms_1$(single measures) of the intra-class correlation coefficient (*Cronbach's alpha*), respectively.

Moreover, regarding the intra-rater comparison of active knee extension ROM performed with photogrammetry (Table 2), very strong and highly significant intra-class correlation coefficients ($ICC_{1,1}$) ($ICC_{1,1}$: $0.91^{3}0.99$; P<0.001) were found in assessments of all groups.

Table 2 Intra-raterintra-class correlation coefficient ($ICC_{1,1}$) values for active knee extension range of motion with computerized photogrammetry

Assessment/groups	Measurements				
	1	2	3	P-value	$ICC_{1,1}$
A1_Cg	147.7±8.3	147.1±7.9	146.4±8.5	0.0001	0.990
A2_Cg	145.3±8.6	145.2±8.6	145.7±9.5	0.0001	0.992
A3_Cg	149.0±9.5	148.5±9.7	148.7±9.6	0.0001	0.997
A4_Cg	146.9±9.7	146.2±9.6	146.4±10.0	0.0001	0.996
A1_SSg	145.8±14.3	145.9±14.1	145.6±14.1	0.0001	0.998
A2_SSg	146.3±13.1	146.5±13.6	146.5±13.5	0.0001	0.997
A3_SSg	149.1±12.0	149.2±11.9	149.7±11.7	0.0001	0.997
A4_SSg	148.0±14.3	148.0±14.7	148.3±14.8	0.0001	0.998
A1_DSg	144,.6±10.6	144.7±10.4	144.8±10.7	0.0001	0.997

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Assessment/groups	Measurements				
	1	2	3	P-value	$ICC_{1,1}$
A2_DSg	144.5±9.2	144.7±9.4	144.8±9.4	0.0001	0.997
A3_DSg	147.8±8.9	147.1±8.6	147.5±9.6	0.0001	0.996
A4_DSg	146.3±9.8	146.6±10.1	143.6±9.6	0.0001	0.997

Measures of groups expressed in mean ± SD.

Legend: A1 = assessment 1; A2 = assessment 2; A3 = assessment 3; A4 = assessment 4; Cg = control group; SSg = static stretching group; DSg = dynamic stretching group.

Note: $ICC_{1,1}$ = $Model_1$ (*one way*) and $Forms_1$(single measures) of the intra-class correlation coefficient (*Cronbach's alpha*), respectively.

However,for inter-instrument comparison (Table 3),*Pearson* test showed weak (r: 0.31–0.6) to strong (r: 0.61–0.9) correlations, in the assessments of the Cg (P<0.05); strong (r: 0.61–0.9) in all assessments of the SSg (P<0.01); and strong (r: 0.61–0.9) to very strong (r: 0.91–0.99) in the assessments of the DSg (P<0.01).

In addition, the ANOVA test showed that there was difference inter-instrument (F = 21.149; P<0.001), with higher means obtained with photogrammetry;however, no difference was found between the groups (F = 0.157; P = 0.855).

Table 3- Measurements of correlation inter-instruments (goniometry×photogrammetry) of active knee extension movement

Measurements	Instruments				
	Goniometry	Photogrammetry	P-value	"r"value	CI 95%
A1_Cg	139.8±7.6	147.1±7.9	0.0001	0.825	0.72-0.89
A2_Cg	136.9±7.9	145.4±8.8	0.0190	0.563	0.36-0.72
A3_Cg	139.2±9.3	148.7±9.6	0.0160	0.573	0.40-0.73
A4_Cg	139.0±9.8	146.5±9.7	0.0040	0.659	0.22-0.78
A1_SSg	136.7±11.2	145.7±13.7	0.0001	0.778	0.65-0.87
A2_SSg	137.4±14.2	146.4±13.4	0.0010	0.748	0.60-0.85
A3_SSg	140.7±12.9	149.3±11.8	0.0001	0.838	0.74-0.90
A4_SSg	138.9±14.2	148.1±14.6	0.0001	0.814	0.70-0.89
A1_DSg	135.9±9.5	144.7±7.9	0.0001	0.912	0.86-0.95
A2_DSg	136.6±10.3	145.1±9.2	0.0060	0.621	0.43-0.76
A3_DSg	140.7±8.2	148.3±9.4	0.0001	0.840	0.74-0.90
A4_DSg	140.1±9.9	147.2±10.0	0.0001	0.866	0.80-0.92

Measures of groups expressed in mean ± SD.

Legend: A1 = assessment 1; A2 = assessment 2; A3 = assessment 3; A4 = assessment 4; Cg = control group; SSg = static stretching group; DSg = dynamic stretching group. Note: r = *Pearson* correlation coefficient*;* CI = Confidence interval.

Discussion

For the present study, regardless of the instrument used, there was very strong reliability between the three measures performed by the same examiner, in each one of the four assessments, to all groups. Similarly,both goniometry and photogrammetry had strong to very strong correlations, although this methodology achieved higher values of ROM in all measures. These results confirm the hypothesis initially suggested that the measurement of active knee extension ROM through photographic analysis is as precise and trustable as the UG, and is considered gold standard for ROM assessments[4].

The data demonstrated a small variability in intra-rater reliability indexes among the measures for both instruments. Previous studies[24] showed that a goniometric measurement error of ± 5° can be clinically acceptable in most situations, however, when facing definitive clinical decisions, such as in surgery cases, it may be less appropriate. According to the results shown here and observing only the repetitiveness of the three measurements in the groups without considering the effect from the intervention, there was an average change of 4.3° (0.5–4.8°) for goniometry and 2.5° (0.2–2.7°) for photogrammetry. These findings prove that both methods were clinically consistent and reproducible by the same examiner, although the data from photogrammetry showed greater reliability and repeatability when compared to goniometry, corroborating the study of Farber, Deorio, Steel[25].

According to Sacco et al.[3],one of the possible explanations for these small differences involves the handling of the goniometer during evaluations; the location of anatomical reference points; and small oscillations in the positioning, since there is no fixation of the instrument on the individual's body, which may interfere with the reproducibility levels of measurements. As César, Gomes, Marques, Domingos, Santos[12] stated, computerized photogrammetry makes it easier to measure ROM because of the use of predetermined passive markers, which can help the accuracy of measurements with less interference of confounding variables.

Although both methods are shown to be reliable for the analysis of active knee extensions, all ROM values obtained by photogrammetric analysis were higher than UG, despite presenting less variability. First, it is important to highlight that both ROM readings were performed by another examiner in order to avoid induction of results, and the assessment with UG was"blind"[22]. Therefore, these findings can possibly be attributed to the identification of anatomical reference points, as the error of a few millimeters in their identification could compromise the obtained angular values[14]. These difficulties were minimized with photogrammetry, because during registration passive markers were fixed for further image analysis, which benefited the alignment of the segments[26].

It should be noted that, despite these minor changes, intrarater reliability in this study was classified as very strong for both instruments, regardless of group or assessment, a fact that reinforces the findings of Brosseauet al.[27], who had found more reliable results for knee ROM (ICC = 0.97) when performed by the same examiner.

Regarding inter-instrument correlation, although there is variation in *r* values, it can be observed that both experimental groups (SSg and DSg) showed strong to very strong correlations (r: 0.62–0.91) when compared to Cg, which obtained weak to strong correlations (r: 0.56–0.82). Many authors[8,14,27] emphasized goniometry as a method widely used in physiotherapeutic clinic for ROM assessments. While photogrammetry is used as a toolfor analyzing postural asymmetries, as well as the flexibility of different segments[10,16], Sacco et al.[3],showed that both methodologies are equally reliable when analyzing other angles such as knee flexion and extension, even though computerized photogrammetry showed higher reliability values (r = 0.97) than goniometry (r = 0.83). According to César, Gomes, Marques, DomingosSantos[12],the availability of a real measure (in degrees) in ROM facilitates its interpretation and allows the perception of subtle changes in the measurements.

Among possible limitations, there is a lack of measurement repeatability of the measurements performed by the same examiner (intra-rater) every other day, by entering a period between them, and also,by a second examiner for the analysis of interrater reliability. Future studies may add these analyses, as that they are relevant in far-reaching or multicentric clinical approaches. In addition, studies emphasizing other age groups, gender, and joints can also be performed.

Conclusion

The results of this study show that, for the analyzed movement, both methodologies (manual goniometry and computerized photogrammetry) showed high reliability and can be used for measuring the active range of knee extension, although photogrammetry has reached higher values in all the measurements. Furthermore, both instruments are correlated, indicating that, proportionally, the measurements vary similarly and are parallel reliable.

Protocol CEP/UFRN n 1.132.671, with Presentation Certificate for Ethics Appreciation (PCEA) n 45188614.2.0000.5537

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