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VALIDITY AND INTRA-RATER RELIABILITY OF LASER GONIOMETER VERSUS ELECTRO-GONIOMETER IN MEASURING SHOULDER RANGE OF MOTION

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ABSTRACT

Background: Providing new objective valid and reliable methods of assessment of a range of motion is always a persistent need for clinical practitioners and researchers in physical therapy for obtaining précised and realistic diagnostic and treatment decisions. So this study was carried out to test the validity and intra-rater reliability of the laser goniometer via comparing repeated measures of laser and electro-goniometers in measuring a range of motion of shoulder movements considering the electro-goniometer as the reference standard.

Methods: one hundred healthy males with ages ranging between 20-30 years shared in this study. Three consecutive measures of bilateral shoulder flexion, abduction, internal and external rotation range of motion were performed by the same examiner on each subject by each of the laser and electro-goniometer, with standardized measurement procedures, subjects' positions, and stabilizations.

Results: Pearson (r), paired T-test, and intra-class (ICC) correlation coefficients were used to test the validity and intra-rater reliability of the laser goniometer in comparison to the electro-goniometer. And the results of the validity testing showed very strong relationship between readings by both devices ($r=0.84$ to 0.93) and also no significant differences between means of readings of both devices with the p-value ranging between 0.13 and 0.97. Also, ICC revealed high intra-rater reliability of laser goniometer on repeated measures of shoulder range of motions ($ICC=0.98-0.99$).

Conclusion: laser goniometer can be used as a new valid, reliable digital objective method of measurement of shoulder range of motion.

Keywords: laser goniometer; electro-goniometer; range of motion; assessment; validity; reliability, shoulder, objective measurement, physical therapy.

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INTRODUCTION

Clinical range of motion (ROM) measurement is an essential evaluation procedure used in physical therapy, and it is known as goniometry which when dealing with musculoskeletal conditions is considered a vital evaluation skill, whose resulting measures can be interpreted to prove the absence or presence of functional affection in the normal mobility of body joints, that is to develop and generate evidence of the effect of treatment strategies [1].

Unfortunately, -till nowadays- the most common way for measuring joint range of motion is the universal plastic goniometer (UG) which is considered as a subjective inaccurate method that suffers from the factor of human error and inconsistency, including the reading and interpretation of the readings [2], improper goniometric application, erroneous specification of the bony landmarks' location, the axis of joint rotation and inability to keep the goniometer's fulcrum on this axis, which affect its validity and reliability. So due to the increased demand of health practitioners toward providing recent qualified services for human health, and the increased orientation about clinical practice based on evidence, efforts are made and continuously done to find reliable and valid clinical objective evaluation tools can be used to evaluate ROM of different joints as it has become important demand for physical therapists for valuable and effective clinical practice [1, 3].

One of the modalities that has become well known as a standardized, valid and reliable method of measuring joint range of motion is the electro-goniometer "ELGON" [1, 4], which converts the angular displacement of the joint into an electric signal readout [3], produced in a simple digital form with measurement's accuracy $\pm 2^\circ$ in range of $\pm 90^\circ$ [2]. So it is used primarily in research studies considering being expensive, time-consuming for calibration [4, 5] and the required skill for application [3], which makes it limiting factor for being used in clinical and practical settings [3-5].

The validity and reliability of electrogoniometer had been evaluated and proven by several studies on different body regions, one of those is the study carried out by Da Silva et al. (2015) to compare the electrogoniometer and the universal goniometer regarding intra-examiner and inter-examiner reliability as well as the inter-device reliability while testing wrist range of motion, and they concluded that electrogoniometer has shown to be a reliable measurement tool for clinical usage when compared to universal goniometer [6]. Another study carried out by Rowe et al. (2001) to assess the validity and reliability of electrogoniometer compared to motion analysis system in measuring knee motion during gait, and they concluded that the electrogoniometer is a valid, reliable instrument providing accurate, precise and stable readings on repeated measures [7].

The laser goniometer is a new modality that has the advantage of the ease and speed measurement of range of motion, it has two laser beams that compensate for the fixed and movable arms of the traditional goniometer configuration, the degree of change of the direction of the laser

beams represent the degree of change of angular displacement of the joint and the readings are shown on an LCD screen in digital form, it just requires to be applied over the region or segment whose range will be measured, and then pressing the zero reference button to determine the zero reference point. By holding the device in the same position during the movement with the laser beams pointing to the bony landmarks all over the measurement, the result can be displayed in the form of digital reading with high precision [2].

This study aimed to test the laser goniometer's validity and intra-examiner reliability in comparison with the electro-goniometer considering the later as the reference standard in providing accurate, consistent and precise measures of range of movement of the different body regions that the physical therapists can rely on in clinical research and practical evaluation approaches.

MATERIAL AND METHODS

Design

This study's research design was a single group within-subject validity and reliability test. Before sharing in this study, a written consent form was signed down by each subject.

Participants

One hundred healthy volunteer male physical therapy students and practitioners from faculty of physical therapy at Misr University for science and technology, with ages, ranging from 20-30 years, heights range between 160-180 cm and body mass indices (BMI) range between 18.5-29.9 kg/m² have shared in this study. This study was carried in the period from 11th June 2016 to 31st August 2016.

Sampling

The sample shared in this study was sequentially selected through an announcement for who would like to share as a volunteer and then the inclusive and exclusive criteria were applied for all the volunteers thus only those that have met the criteria have shared and who not were excluded.

Materials

- *Weight scale*: A CAMRY mechanical personal weight scale Model BR5002 with serial no. C101100430, shown in Fig. 1; was calibrated before measuring each subject's weight.



Figure1: CAMRY Weight scale

-An adhesive ruler and water bubble scale: for measuring height sticker ruler from IKEA adhered to the wall and a water bubble scale were used to measure the participants' height as shown in Fig. 2.

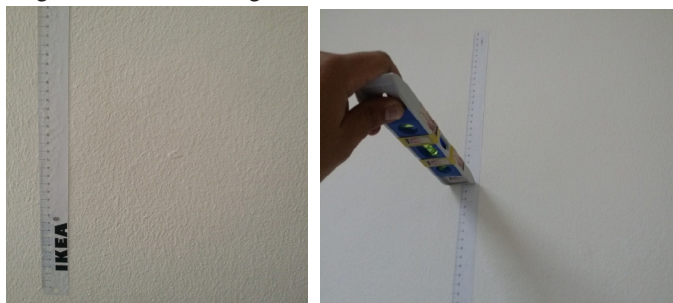


Figure 2: IKEA adhesive sticker ruler and water bubble scale for measuring height

- Chair: standard 110° back reclined chair
- Plinth.
- Straps for stabilization.
- Small sheets: for padding at humerus during measuring shoulder rotation movements.
- The electro-goniometer

The digital electro-goniometer - model 12-1027 – that works by an electrical signal induced by means of a battery was used as the reference standard in this study. The device converts the angular displacement of the joint (represented in the degree of change of the angle between the two arms of the device) into an electric signal readout [3], which is produced in a simple digital form [2] as shown in Fig. 3.



Figure 3: The Digital Electro-goniometer.

-The laser goniometer

The laser goniometer HALO which is class 1 laser product with maximum out the power of 0.39 mW and wavelength of 635 nm – model HG1 - serial no. HG1XSH225G - designed in Australia, made in Malaysia, was used as the tested device in this study, it has 2 laser beams that compensate for the fixed and movable arms of the traditional goniometer configuration, the degree of change of the direction of the laser beams represent the degree of change of angular displacement of the joint and the readings are shown on an LCD screen in digital form, shown in Fig. 4.



Figure 4a: The digital laser goniometer HALO with the two laser beams emitting from it.



Figure 4b: HALO configurations.

Procedures

Weight and height and body mass index score of each of the participants who shared in this study were measured, then the inclusion and exclusion criteria were applied. Each participant of those who met the criteria was asked to sit for a while until he feels rested while the whole idea and procedures of the study were explained to him, and then after his approval to share in the study, he was asked to sign the consent form.

The sequence of movements' measurement was randomly performed for each patient to avoid effect of sequencing on the examiner's decisions or measurements. Also, the sequence of devices used in measurement was randomized for each patient and each movement to avoid bias by the examiner.

Shoulder flexion, abduction, internal, and external rotation were measured bilaterally. Range of movement of each of these selected joint movements was measured for three consecutive times by the same examiner on the same subjects for each side, by each of the laser and electro-goniometers, one after another, taking into consideration the standardization of all the measurement procedures, subjects' positions, and stabilizations, considering the electro-goniometer as the reference standard. Each subject was asked to take off any clothes that may restrict movement of the measured region and to perform active range of motion for each of the tested movements for each joint with the assumption that each of the participants have followed the instructions strictly and acted freely, efficiently and in the same way while performing these movements during taking the repeated measures by both devices.

For measuring the selected shoulder movements, the position used as the supine position, in which the participant was asked to lie down restfully on his back with his trunk bare skin to allow free movement of both arms during measurement of each side, stabilization with straps to the chest region was applied to avoid substitutions by trunk movement [3, 5].

For shoulder flexion, the starting position for the participant's arm was beside his body with the elbow extended

and the thumb pointing upward. The axis of measurement was the lateral part of greater tubercle and the lateral epicondyle as the reference point. The fixed arm was placed parallel to the surface of the floor, the movable arm was placed parallel to the lateral aspect of the upper arm (humerus) [3, 5], as shown in Fig. 5.



Figure 5a: Measuring shoulder flexion using an electrogoniometer.



Figure 5b: Measuring shoulder flexion Laser goniometer.

For shoulder abduction, the starting position for the participant's arm was laterally rotated beside his body with the elbow extended and palm facing upward without flexion or extension of shoulder. The axis of measurement was the anterior aspect of the acromion process and the medial epicondyle as the reference point. The fixed arm was placed parallel to the surface of the floor, the movable arm was placed parallel to the anterior aspect of the upper arm (humerus) [3, 5], as shown in Fig. 6.



Figure 6a: Measuring shoulder abduction using electrogoniometer.

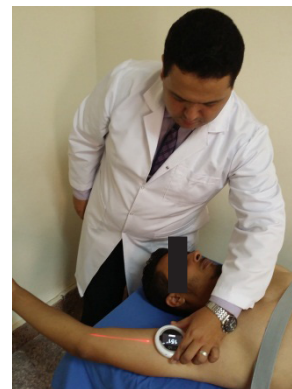


Figure 6b: Measuring shoulder abduction using a laser goniometer.

For shoulder internal and external rotation, the starting position for the participant's arm was abducted 90° and elbow flexed 90° with the forearm perpendicular on the plinth, with his palm facing toward his feet without forearm pronation or supination and elbow outside plinth, a small pad was used under the humerus to be in level with the acromion. The distal end of humerus, thorax, and clavicle was stabilized. The axis of measurement was the olecranon process, and the ulnar styloid process as the reference point [3, 5], internal rotation shown in Fig. Seven and external rotation is shown in Fig. 8.



Figure 7a: Measuring shoulder internal rotation using electrogoniometer.



Figure 7b: Measuring shoulder internal rotation using a laser goniometer.



Figure 8a: Shoulder lateral rotation Using an electrogoniometer.



Figure 8b: Shoulder lateral rotation using a laser goniometer.

Statistical methods

Correlation between measures obtained by both devices was done by using Pearson's correlation coefficient (r); also comparison using paired T-test was done, to test laser goniometer's validity about the electrogoniometer as a reference standard.

Intra-rater reliability of the laser goniometer has been measured on repeated measures using intra-class correlation coefficient (ICC) value at confidence level (CI) 95%.

RESULTS

One hundred healthy males have shared in the study with mean \pm SD ages, weights, heights, and Body mass indices as follows 21.53 ± 2.15 years, 75.03 ± 12.68 kg, 173.81 ± 5.58 cm, and 24.73 ± 3.41 kg/m² respectively, shown in table 1.

Table 1: Descriptive statistics for the mean age, weight, height and BMI of the study group.

	$\bar{X} \pm SD$	Minimum	Maximum	Range
Age (years)	21.53 ± 2.15	20	30	10
Weight (kg)	75.03 ± 12.68	50	96	46
Height (cm)	173.81 ± 5.58	160	180	20
BMI (kg/m ²)	24.73 ± 3.41	18.69	29.65	10.96

\bar{X} : Mean

SD: Standard Deviation

Corresponding to validity, the results of the correlation between the measures of both devices in shoulder range of motions are presented in Figs. 9-16.

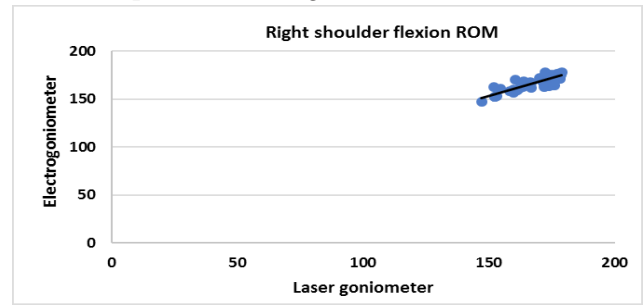


Figure 9: Right shoulder flexion ROM.

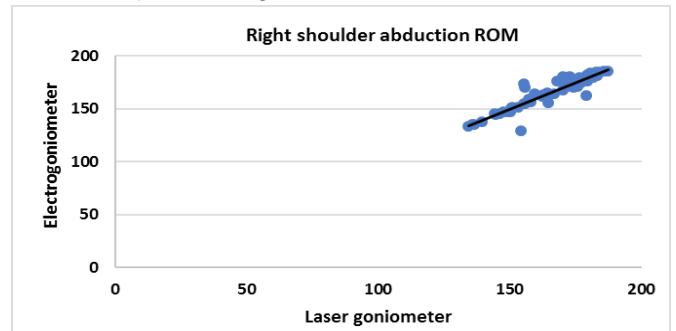


Figure 10: Right shoulder abduction ROM.

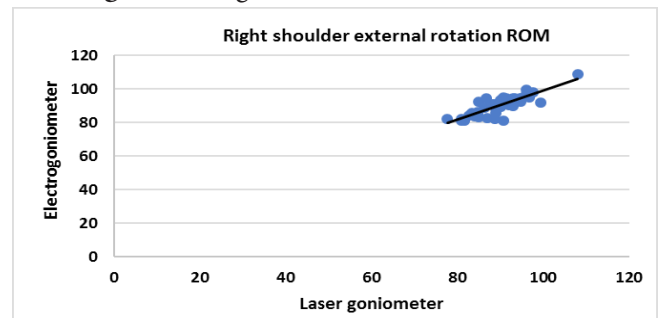


Figure 11: Right shoulder external rotation ROM.

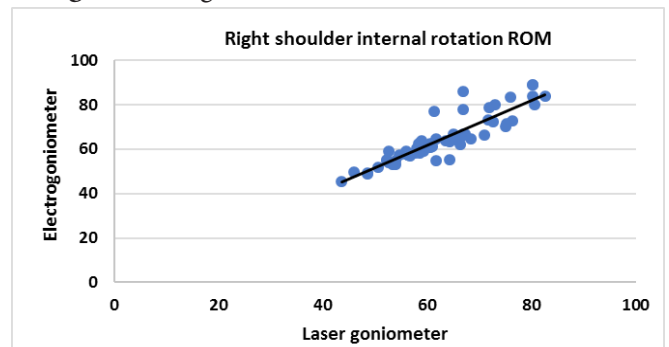


Figure 12: Right shoulder internal rotation ROM.

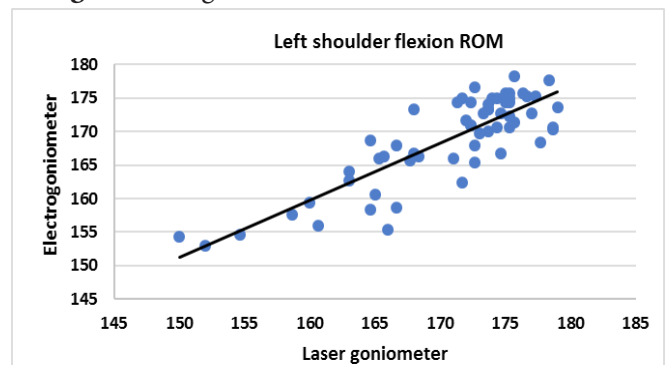


Figure 13: Left shoulder flexion ROM.

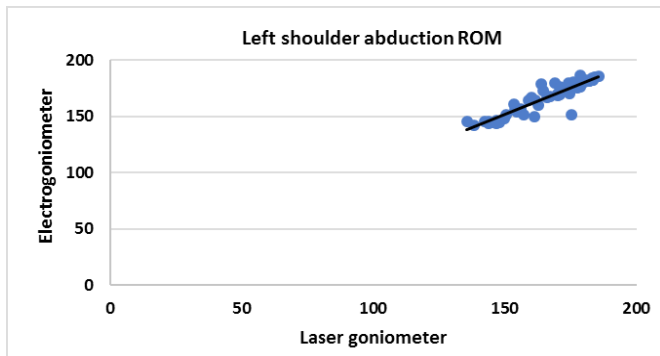


Figure 14: Left shoulder abduction ROM.

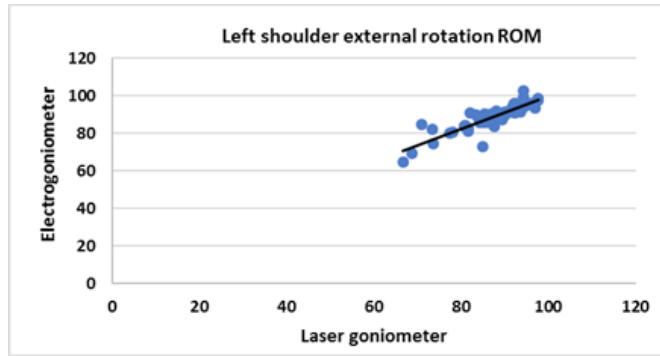


Figure 15: Left shoulder external rotation.

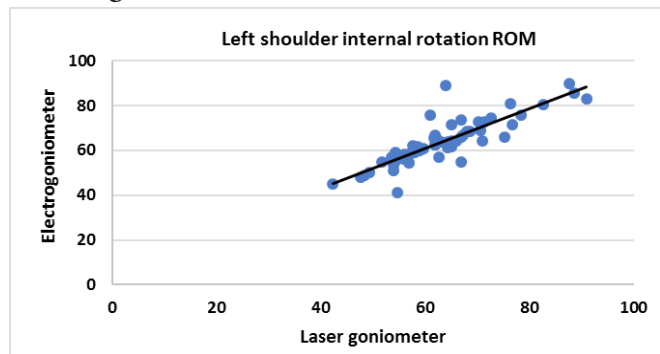


Figure 16: Right shoulder internal rotation ROM.

The correlation and paired t-test between ROM of the right shoulder measured by laser goniometer and that measured by electro-goniometer were very strong positive significant correlation, with the r-value equals 0.86, 0.93, 0.89, 0.84 and the p values equals 0.36, 0.97, 0.72, and 0.35, for flexion, abduction, internal rotation, external rotation respectively, with the level of significance set to 0.05, as shown in Table 2.

Table 2: Descriptive analysis, Correlation, and comparison between shoulder ROM measured by laser goniometer and that measured by electrogoniometer:

	Shoulder ROM (degrees)	Laser goniometer	Electro-goniometer	r value	t-value	P-value	Significance
		$\bar{X} \pm SD$	$\bar{X} \pm SD$				
Right shoulder	Flexion	169.52 ± 8.11	168.26 ± 7.05	0.86	0.9	0.36	NS
	Abduction	166.74 ± 14.77	166.67 ± 15.82	0.93	0.02	0.97	NS
	External rotation	90.56 ± 5.13	90.89 ± 5.21	0.84	-0.35	0.72	NS
	Internal rotation	62.67 ± 9.39	64.36 ± 10.62	0.89	-0.92	0.35	NS

Left shoulder	Flexion	170.7 ± 6.56	168.86 ± 6.64	0.84	1.52	0.13	NS
	Abduction	167.88 ± 14.15	168.77 ± 14.41	0.93	-0.34	0.73	NS
	External rotation	87.22 ± 6.86	88.62 ± 6.83	0.86	-1.11	0.26	NS
	Internal rotation	63.19 ± 9.96	63.77 ± 10.26	0.85	-0.31	0.75	NS

\bar{X} : Mean

SD: Standard deviation

r value: correlation coefficient value

P-value: Probability value NS: Non-significant

The correlation and paired t-test between ROM of the left shoulder measured by laser goniometer and that measured by electro-goniometer were very strong positive significant correlation with the r-value equals 0.84, 0.93, 0.85, 0.86 and the p values equals 0.13, 0.73, 0.26, and 0.75, for flexion, abduction, internal rotation, external rotation respectively, with the level of significance set to 0.05, as shown in Table 2.

Corresponding to the reliability, laser goniometer showed high intra-examiner reliability in all shoulder ROM measurements with intra-class correlation coefficient (ICC) value of 0.98-0.99, as shown in Table 3.

Table 3: ICC for intra-rater reliability of laser goniometer in the measurement of shoulder ROM:

Shoulder ROM	ICC	(95% CI)		
		Lower bound	Upper bound	
Right shoulder	Flexion	0.99	0.98	0.99
	Abduction	0.99	0.99	0.99
	External rotation	0.98	0.97	0.98
	Internal rotation	0.99	0.99	0.99
Left shoulder	Flexion	0.98	0.98	0.99
	Abduction	0.99	0.99	0.99
	External rotation	0.98	0.98	0.99
	Internal rotation	0.99	0.98	0.99

DISCUSSION

In order to develop and overcome the low validity and reliability of the traditional plastic universal goniometer, many strategies have been taken to develop other types of goniometers. A study carried out by Carey et al. (2010) was done to test reliability and validity of digital goniometer in comparison to universal goniometer and revealed that the digital goniometer could be used as a valid and reliable method of measuring range of motion [8]. Milanese et al. (2014) carried out a study to compare a smartphone application (the knee goniometer app (ockendon©)) (KGA) with the universal goniometer in measuring knee angle range of motion by three physiotherapists of seven years' experience and three students at final year of studying physiotherapy thus to test the consistency of the readings obtained, the results showed that both devices were reliable on repeated measures with the smartphone having smaller

error of measurement values [1].

Brosseau et al. (1997) carried out a study to test the criterion validity, intra and inter rater reliability of parallelogram goniometers in comparison to universal goniometers applied on sixty healthy subjects regarding active knee flexion, the results showed that the parallelogram was valid and reliable as well as the universal goniometer with the advantage of fast and few adjustments' application of parallelogram [9].

Valid, objective and reliable ROM measures can be obtained by using digital images, radiographs, photocopies, photographs, plumb line, electro-goniometer, and flexometer, but all those are not always available to be used in clinical or practical setting [4], other examples of goniometric devices include the inclinometer (also known as the bubble goniometer, gravity goniometer, and pendulum goniometer), and video recording equipment. Of these mentioned devices, the inclinometer is the most probably and widely used, since it is portable and is relative to low cost [3].

The validity and reliability of the electro-goniometer for measuring a range of motions of different regions have been studied, and the results of these studies had proved that the electro-goniometer could be used as an objective valid and reliable method in measuring range of movement of different body regions. One study was carried out by Bronner et al. (2010) comparing the electrogoniometer to digital protractor and motion analysis in measuring range of motion of sagittal plane angular movements of the hip, knee and ankle, the intra-rater correlations and the correlations to the protractor and the correlations of concurrent validity in relation to the motion analysis were all high [10].

A study carried out by Mullaney et al. (2010) to compare a construction grade digital goniometer with the universal goniometer in measuring shoulder joint active-assisted range of motion in 20 patients with unilateral pathology, the results showed that the digital goniometer is highly reliable but cannot be used interchangeably with the universal goniometer [11].

A study was carried out by Feipel et al. (1999) to establish clinical reference and normal database of active range of motion of cervical spine using electrogoniometer on 250 asymptomatic volunteers cervical and they stated that the results they had obtained agreed with previous observations, which indicated the validity of the methodology used [12].

Another study carried out by Tajali et al. (2016) to test validity, intra and inter tester reliability of two electrogoniometers in measuring active range of motion of hand and wrist and passive flexion of proximal interphalangeal joint of index finger in 44 patients with limited motion, the results showed high Intra and inter tester reliability coefficients in measuring active wrist and hand range of motion and passive flexion of proximal interphalangeal joint of index finger in patients with limited range of motion [13]. So in regard to validity, it is believed that the electro-goniometer is nowadays used as a standardized, valid, reli-

able, and accurate, objective method of measuring range of motion of different joints [1, 4], so it can be used as a reference standard to test and compare the readings and results of measuring range of motion taken by another new measurement tool.

The laser goniometer HALO is a newly arising device designed for range of movement measurement, it is featured and characterized by being easy and not consuming time for obtaining the measurement, it just requires to be applied over the region or segment whose range will be measured, the emitting 2 safe low-level laser beams replace the stationary and movable arms of the universal goniometer and then pressing the zero reference button to determine the zero reference point. By holding the device in the same position during the movement, the result can be read from a digital display with a high degree of precision [2].

In our study the range of movement of flexion, abduction, lateral and medial rotation of both shoulders were assessed by the same examiner using the laser goniometer and the electro-goniometer - with standardization of all the measurement positions and stabilization in all measures for all subjects - that is to compare the results of measurements of both devices, using the electro-goniometer as the reference standard, to determine the validity and intra-rater reliability of the laser goniometer.

This study's results showed no significant difference between the measurements obtained by the laser goniometer and those obtained by the electro-goniometer in all the tested shoulder movements, and there was consistency of the readings taken by the laser goniometer. This may be due to the precision and the accuracy and sensitivity of the laser goniometer to any change of the angular displacement of the device represented in the shift in the direction of the laser beams.

With regards to shoulder range of motion, the results showed that there is strong to the excellent relationship between the readings of both devices in measuring all shoulder movements.

Concerning reliability, the laser goniometer showed that it has very high intra-class correlation coefficient values that mean that it has excellent intra-rater reliability on repeated measures for each movement on each side for each subject. This showed that the laser goniometer capable of providing high precision, accuracy, and consistency in measuring the involved movements repeatedly. The factor of long practical experience and training of the examiner and the good standardization each procedure of each measurement help to leading for these high-reliability correlation coefficient values [14].

The results of our study agree with another research carried out by Choi & Kang (2015) in which comparison was done between intra-examiner and inter-examiner reliability of 3 devices; an inclinometer, a laser beam goniometer, and traditional goniometer while performing test of Craig and measuring the anteversion of femur by 2 examiners, the results showed that the 3 methods have high intra-rater

reliability goniometer with laser beam having the highest reliability scores corresponding to the 2 examiners, also the goniometer with laser beam showed to have high intra-examiner reliability and moderate inter-examiner reliability while the scores of other modalities were low. They referred this to the advantage that the beam provided by the laser acts as a good reference for the vertical axis of femur that helps to ensure more accuracy of measurement [15].

CONCLUSION

Laser goniometer can be used as a valid and reliable digital objective method of measuring the shoulder range of motions as a standardized alternative for the electro-goniometer that physical therapists can rely on in research studies and clinical practice.

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