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Measurement of Neck-Shaft Angle Using CT Scout View in Healthy Jordanian Adults - A Reliability and Agreement Study

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Authors' contributions

This work was carried out in collaboration among all authors. Author IA contributed in conceptualizing the study, done the Data collection, data analysis and interpretation, drafting the article, critical revision of the article and final approval of the version to be published. Author MM contributed in conceptualizing the study, data collection, drafting the article, critical revision of the article and final approval of the version to be published. Author HH contributed in figuring the conception of the study, data collection, drafting the article and critical revision of the article. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To report estimates of the reliability and agreement of a new method for measuring the femoral Neck-shaft angle in the Jordanian population. The neck-shaft angle is an important anatomical indicator in orthopedics of the hip. While there are different approaches to measuring the neck-shaft angle in the literature, there is no agreement on the best technique used for measurement. CT scout view was used in this study to provide a promising alternative.
Study Design: Observational reliability and agreement study.
Places and Duration of the Study: Department of physiotherapy, school of rehabilitation science, University of Jordan and University of Jordan Hospital between March 2014 and October 2015.

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Methodology: Two independent raters calculated the neck-shaft angle on each hip of 50 pelvic CT scout images of healthy adults to determine inter-rater reliability. One rater performed the measurement twice to determine the intra-rater reliability. Intra-class correlation coefficients were used to examine relative reliability. The standard error of measurement (SEM) and 95% minimal detectable change (MDC) were calculated to examine absolute reliability.
Results: The mean value of all angle measurements was 131.3. Intra-class correlation coefficients were 0.726 and 0.63 for inter and intra-rater measurements respectively. SEM and MDC for inter-rater measurements were 2.69 and 7.46 respectively. For intra-rater measurements, they were 2.84 and 7.86 respectively.
Conclusion: The new method proposed in this study for measuring the neck-shaft angle showed good reliability and small measurement error.

Keywords: Neck-shaft angle; reliability; CT scout images; standard error of measurement; minimal detectable change.

1. INTRODUCTION

Neck-shaft angle (NSA), the angle between the axis of the neck of the femur and its shaft, is an important anatomic indicator of hip pathologies. Its average normal values is127 degrees, as identified in a large-scale global review of 8271 femora of 101 human groups belonging for more than 80 countries and territories [1]. NSA values are used to aid in the diagnosis of hip abnormalities in children such as developmental dysplasia [2]. It is also used to guide the implant's placement and postoperative function in hip arthroplasty procedures [3]. An increased NSA value is associated with a high risk of hip fractures [4,5]. Yet despite the prevalence of hip pathologies reported in the Jordanian population [6], the normal NSA measurement is not reported in the literature. Orthopedic surgeons rely on values that are based on the Caucasian population, which may not apply to the Jordanian population [1].

Accurate measurement of NSA values is a widely discussed topic in the research of clinical orthopedics. The traditional use of plain radiographs for measuring NSA is critiqued for the wide-ranging calculation methods, which affects reliability and measurement accuracy [7, 8]. CT scans-based measurements are found to have comparable validity and reliability estimates as plain radiographs [7-9], or better [10-12]. However, radiation from plain radiographs and CT scans may be hazardous [13,14].

The use of CT scout images provides a safer alternative than regular CT scans by reducing radiation exposure [15], with an ability to detect pathological changes in conditions such as fractures, metastases, and avascular necrosis [16,17]; as well as determining lower limb alignment and geometry [18]. CT scout image is not reported as a measurement method for NSA and its reliability is unknown. This study aims to determine NSA values using two-dimensional (2D) pelvis CT scout images and estimate reliability and agreement of this new method for NSA measurement.

2. MATERIALS AND METHODS

The CT scout images used in this study were taken from healthy subjects residing in Amman, the capital city of Jordan. Exclusion criteria were: age below 20, fracture or deformity in the pelvis or femur, the existence of hip or femur implants, visible hip OA on the radiograph. Participants were recruited between March 2014 and October 2015 during their involvement in another study that investigated age-related changes in the cross-sectional area of the thigh region. Participants from the original study were recruited if they were 20 years old or older and could walk independently without using assistive devices. Subjects were excluded from participation if they had any cardiovascular, respiratory, neuromuscular diseases, inflammatory arthritis, muscular disorders, or were participating in a regular exercise program. Power analysis was performed using G-power software (version 3.1.9.2 for Mac, Universität Düsseldorf) which showed that for a sample of 100 NSA measurements, using repeated measures within factor ANOVA and an alpha level of .05, a power of more than 97% is achieved.

2.1 Measurement Methods

Two-dimensional (2D) pelvis CT scout images were taken by positioning participants in the supine position with their lower extremities

extended flat on the scanner's table while keeping the hip joints in neutral rotation. NSA was measured on images using commercially available software (SliceOmatic, version 5.0 revision 5f, Montreal, Canada) [19] that provides various 2D measurement tools such as ruler, arrow, and protractor. The measurements were performed on 50 CT scout images including both hips providing 100 measurements in total.

The measurements were performed on a computer with a screen size of 24 inches. The measurement protocol involved loading CT scout images on the software. Images were magnified according to the rater's optimal view. From the software menu, 2D tools were activated. Two rulers were selected; one was placed on the neck of the femur parallel to its axis and the other on the shaft of the femur parallel to its longitudinal axis (see Fig. 1A). Next, two arrows were selected, one was placed in the middle of the ruler on the femoral neck axis and the other in the middle of the ruler on the femoral shaft axis (see Fig. 1B). Then both rulers were removed keeping the arrows in place (see Fig. 1C). Then, a protractor was selected, one end of the protractor was fitted on the arrow on the neck of the femur and the other end was fitted on the arrow on the shaft of the femur. The axis of the protractor was placed on the intersection of the arrows, then the neck-shaft angle was recorded (see Fig. 1D). The same process was repeated on the contralateral femur.

2.2 Reliability Testing Methods

The instructions on how to navigate the software and the protocol measurements were given to raters. Three raters with 10-15 years of reading orthopedic imaging performed the measurements. To determine inter-rater reliability, two raters independently measured the NSA on each hip of the 50 CT scout images. Data was kept on a password-protected computer and the raters were unable to access each other's results. To determine the intra-rater reliability, another rater performed two measurements separated by four weeks, the rater was blinded to his first-time results.

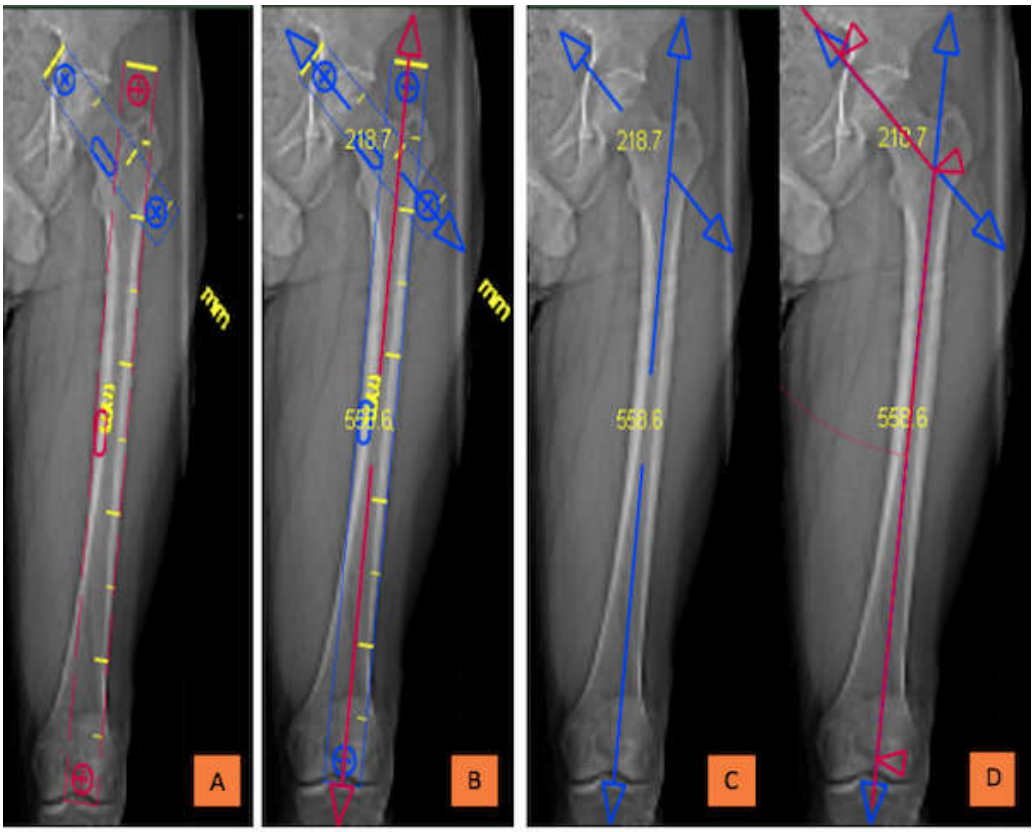

Fig. 1. Steps for measuring neck-shaft angle: A. Rulers were placed on the neck and shaft of the femur. B. Arrows were placed on the centers of the rulers. C. Rulers were removed keeping the arrows in place. D. A protractor was placed on top of the arrows

2.3 Statistical Analysis

SPSS version 20 (IBM, SPSS statistics 2009) was used to execute all statistical procedures. Intra-class correlation ICC (2-way random model (2, 1), type consistency) were calculated to examine intra and inter-rater reliability. ICC values were considered poor if it is between 0.00 to 0.4, fair to good between 0.40 – 0.75 and excellent if more than 0.75 [20]. ICC is considered as a relative measure of reliability, and it represents the proportion of total variability in the measurement that is accounted for by between subjects' variability [21].

The standard error of measurement was also calculated to quantify the amount of error for both inter and intra-rater measurements. SEM was computed based on the following formula once for inter-rate measurement and another for the intra-rater measurement

$$SEM = SD\ pooled\ X\ \sqrt{1 - ICC}$$

Where SD pooled is the pooled standard deviation for the repeated measurements and ICC is the intra-class correlation coefficient for inter- and intra- rater measurements [22].

Minimal detectable change at 95% confidence level ($MDC_{95\%}$) was also calculated for both inter- and intra- rater measurements. $MDC_{95\%}$ was utilized to determine the smallest difference that is considered a real difference in the measurement. $MDC_{95\%}$ was calculated using the following formula [8].

$$MDC\ 95\% = SEM\ X\ 1.96\ X\ \sqrt{2}$$

3. RESULTS AND DISCUSSION

CT scout images of the hip region from 50 healthy adult Jordanians were analyzed, providing a total of 100 hip measurements for each rater. The mean age of the participants is 50.72 years (range 21 – 82 years). This sample included 36 female (36%) and 64 male (64%) femora. The average height and weight of the sample were 1.67m (SD= 8.77) and 85.29kg (SD=16.88) respectively.

3.1 NSA Values

The mean value of all NSA measurements was 131.3 (4.8) range 120.5 –143. Table 1 presents the NSA values based on gender and laterality for each rater and the average for both raters. There were no observable differences on the NSA measurements between males and females for each rater. Also there were no differences on the NSA measurements between right and left sides for each rater. Furthermore there were no differences between raters on NSA measurement based on gender and laterality.

3.2 Agreement

The average of NSA was 131.6 (range: 117 – 142) and 130.9 (range: 120.3 –146) degrees for the first and second raters' respectively. There was no significant difference between raters' measurements as determined by repeated measures ANOVA ($F(1,99) = 4.938$, $P=0.061$).

The averages of the NSA obtained by the same rater over 2-time points were 130.9 and 127.6 (range for second reading: 119.2 –139.4) degrees. There was a significant difference between the rater's measurements as determined by the repeated measures ANOVA ($F(1,99) = 68.096$, $P<0.001$).

3.3 Reliability

Intra-class correlation coefficients for inter- and intra-rater measurements along with SEM and $MDC_{95\%}$ are presented in Table 2.

3.4 Discussion

In the current study, accuracy was perceived as having both reliability and comparability to established healthy adult NSA values in the literature. The proposed method can be generalized to be used by orthopedic surgeons and radiologists to determine NSA values as it proved to be both accurate and reliable.

The average value of the NSA in the Jordanian population is slightly higher than the average human value of 127 degrees as measured in a large-scale global review [1]. Moreover, the average value identified in this study is comparable to other values of various countries reported in the literature (Table 3). This indicates that the use of CT scout images can lead to accurate measurements.

The mean value for NSA for male and female participants was similar to those reported in the literature [1]. Yet, other studies found that males had higher values than females (Table 3), which was linked to the wider pelvis and greater obliquity of the femur in females. Moreover,

although some studies negated the existence of laterality difference [11,23], or reported a difference in favor of left side [1], right side values were slightly higher than the left side in this study, which is similar to data reported for the Nigerian and Chinese populations [24,25]. This small lateral difference can be attributed to right side dominance.

ANOVA test shows significant results if the difference between repeated measurements is large or the error term is small or both. The difference between NSA measurements for the same rater was 3.3 degrees which are considered a small difference and clinically insignificant. Furthermore, the error term for the repeated measurements is considered small (mean square error = 8.04). Consequently, a sample of 100 measurements with such a small error term would produce a significant result even with a small difference in repeated measurements.

The ICC for inter- and intra- rater observations showed good reliability [20]. ICC is considered a relative measure of reliability [21]. It represents the proportion of total variability in the measurement that is accounted for by between subjects' variability [21]. Therefore, large variability between subjects on the measurement of interest will result in a large value of the ICC and vice versa [21]. Although our sample included subjects with wide-ranging age, the variability of NSA measurements was small as evident by the small standard deviation (SD rater 1 = 5.08; rater 2 = 5.21). Therefore, between subjects' variability was not large to produce larger values for ICC.

To generalize our method of measuring NSA, a 2-way random model ICC calculation was performed instead of a 2-way mixed effect ICC model used in other NSA reliability studies [30,31]. In the 2-way mixed effect ICC model, the total variability excludes the systematic error from the model calculations compared to the 2-way random effect which considers both random and systematic errors [21]. Therefore, the total variability in the mixed effect ICC model will be smaller than the random effect ICC model. Accordingly, ICC values for the mixed effect model will be larger.

Table 1. NSA values based on gender and laterality

Measurement		Mean	STD	Range
1st rater	Male	132.3	5.0	119.0-142.0
	Female	131.3	5.4	117.0-141.0
	Right	132.1	4.7	117.0-142.0
	Left	131.1	5.3	121.0-142.0
2nd rater	Male	131.0	5.2	122.2-141.6
	Female	131.3	5.6	120.9-146.0
	Right	131.5	4.9	122.8-142.9
	Left	130.3	5.4	120.3-146.0
Average values	Male	131.7	4.5	122.0-141.3
	Female	131.3	5.2	120.5-143.0
	Right	131.8	4.4	120.5-141.0
	Left	130.7	5.0	121.6-143.0

Table 2. Intra-class correlation coefficients, standard error of measurements and minimal detectable change for inter and intra rater measurements

	ICC[a] (95% CI[b])	SEM[c]	$MDC_{95\%}$[d]
Inter-Rater			
Single (2,1)	0.73 (0.62-0.81)	2.7	7.5
Averaged (2,2)	0.84 (0.76-0.89)		
Intra-Rater			
Single (2,1)	0.63 (0.50-0.74)	2.8	7.9
Averaged (2,2)	0.77 (0.66-0.85)		

a: Intra-Class correlation coefficient
b: Confidence interval
c: Standard error of measurement
d: Minimal detectable change

Table 3. Neck-shaft angle values in the literature

Country / Race	Imaging method	population	Sample size	NSA values average	NSA values Males	NSA values females	Right	Left
Spain [26]	Dual-energy X-ray absorptiometry	Healthy subjects and hip fracture patients	545 + 411		130.6 (4.7) 126.3(4.4)	129.6 (5.3) 124.6 (4.2)		
UK [23]	AP x-ray	Healthy subjects and hip OA	1,123+ 1007	128			128.34 (7.06)	128.34 (7.06)
Thailand [27]	CT scan	cadaveric specimens	108	128.04				
Central Europe [10]	CT scan	Emergency patients	800	133.63	133.0	134.3	133.6	133.7
USA (Caucasian and African American) [28]	Digital photograph	cadaveric specimens	375	129.2 (6.24)				
Mixed [11]	None (direct measurement)	cadaveric specimens	8000	127	125.21 (5.5)	125.17 (5.6)	125.7 (5.4)	127 (5.7)
Mixed [29]	Digital photograph	cadaveric specimens	200	132.7 (5.91)	134	131.5		
Korea [30]	AP x-ray	Healthy subjects	200	129.9			129.6	130.2
Nigeria [24]	AP x-ray	Healthy	264	130.77	131.6	129.9	131.2	130.2
China [25]	CT scan or x-ray	Healthy	466	133	133.1	132.6	133.2	132
Current study Jordan	CT scout images	Healthy	100	131.3	131.2	131.3	131.8	130.7

To determine NSA measurement fluctuations, SEM was computed for both inter- and intra-rater measurements. SEM is considered an absolute indicator of reliability. SEM and $MDC_{95\%}$ values reported in this study are small when compared to Mast et al [32]. The SEM for both inter- and intra-rater were similar and less than 3 degrees. Therefore, different raters are estimating the NSA value for each individual with less than 3 degrees of error. The same precision was found for one rater over 2-time points. SEM was then used to determine $MDC_{95\%}$. MDC is another indicator of absolute reliability and defined as the smallest difference in the measurement that is considered a real difference. This study identified that $MDC_{95\%}$ for both inter- and intra-rater were also similar and they were less than 8 degrees. Consequently, 2 different measurements on the same individual, either from different raters or from the same rater over 2-time points, that are less than 8 degrees apart are not considered different from each other.

3.5 Limitations

CT scout images used in this study were from another study that used scout images to take the slice image of the midthigh region. Those images did not show contours of the proximal femur with ample clarity. This might be a source of error in the NSA measurements. Accuracy of measurements was assumed compared to literature while comparing the results of CT scout images with CT scans can further support the accuracy of the method.

When using 100 hips from 50 CT scout images, there will be an association between the magnitudes of the NSA from the same patient. That could lead to a limited variability of the NSA measurements. Accordingly, that might reduce the ICC values.

The significant difference in the intra-rater readings might be due to the learning effect. The rater became more efficient in using the measurement tools of the Slice Omatic software during the second round of measurements.

4. CONCLUSION

Despite the above-mentioned limitations, our new method for measuring NSA showed good reliability. Furthermore, our new method revealed its ability to reproduce measurements with limited measurement error as indicated by small SEM and MDC95%. Participants in this study were healthy subjects, future studies should investigate this method of measurement in people with hip pathologies.

CONSENT AND ETHICAL APPROVAL

All study procedures were approved by the institutional review board of the University of Jordan Hospital. All participants gave their informed consent.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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