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AGE AND GENDER DIFFERENCES IN MODIFIED FEMORAL NECK-SHAFT ANGLE: AN MRI BASED OBSERVATIONAL STUDY

Orthopaedics

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ABSTRACT

Background: Femoral neck-shaft angle has its importance in describing biomechanics of hip. Measurement methods like plain radiography and CT scans have its limitations. The modified neck-shaft angle (mNSA) drawn on MRI scans is less susceptible to rotational effects and is more reliable for getting normal values. The present study was undertaken to assess the neck shaft angle on MRI and establish differences according to age and gender. **Methods**: Total 200 adults were recruited and equally distributed under four study cohorts according to age and gender. MRI of hip joint was analysed and mNSA was measured using pre-defined axial lines and landmarks. **Results**: The mean age of the participants was 49.76±18.184 years (18 to 87 years). The mean mNSA was 147.855°. Males had significantly higher mean mNSA (149.93±6.61)° than females (145.78±5.71)°. Though the younger age group (<60 years) had higher mNSA values (148.32±6.65) than older (> 60years) age group (147.3900±6.35), the difference was not statistically significant. **Conclusions:** We conclude that gender-based variation exists in the population with the higher values of mNSA in males as compared to females in any age group. The age based difference is also present, but it is not significant. Neck shaft angle calculated on the MRI has the advantage that it is unaffected by rotation of the hip and is radiation free. The orthopaedic surgeons can use the mNSA for the diagnosis and planning surgeries around hip, for designing implants and prosthesis. It can also be of help for the forensic anthropologists and to the anatomists. Multicentric studies may be undertaken to include a larger population.

KEYWORDS

MRI hip, modified neck-shaft angle, proximal femur geometry.

INTRODUCTION

The Hip joint is weight-bearing joint which is supported through robust muscle groups and ligaments [1]. Femoral head inclination, measured as neck-shaft angle, is essential in describing biomechanics of the hip joint. The neck-shaft angle (NSA), also known as the Caput - Collum- Diaphyseal angle (CCD angle) is the angle subtended by the femoral head with the shaft of femur in the coronal plane [2].

NSA plays a pivotal role in the biomechanics of the hip joint. Gait changes occurring in hip pathologies like congenital dysplasia of the hip, cerebral palsy (CP), congenital coxa vara, etc., have relation to change in normal neck-shaft angle[3]. Femoral neck-shaft angle is also an important predictor for femur neck fractures in osteoporotic postmenopausal women[4].Surgeries on the proximal femur are aimed to remove pathology and restore anatomy and biomechanics as far as possible. Precise measurement of neck-shaft angle is valuable not only for pre-operative templating in complex surgeries like total hip arthroplasty (THA) but also for calculating the angle for osteotomies and for fracture fixations. This can help in reducing the number of complications[5].

The value of neck-shaft angle varies with age, being very high during the neonatal period. It becomes more varus with increasing weight-bearing and activity level during childhood, becomes stable in mid-adolescence to adulthood period and may decrease gradually in more advanced age[6]. Studies have also shown gender-specific differences in neck-shaft angle, stating that females have smaller neck-shaft angle which relates to their wider pelvis and shorter length of femur while some studies have also shown higher values for females[7,8]. Nelson and Megyesi (2004) researched ethnic and sex variations in bone structure and consequently established the want for creating gender-specific implants [9].

Several methods have been proposed in the past for the measurement of the neck-shaft angle. Methods such as radiography, dry bone measurement and Computerized Tomography scan (CT) are there in literature, but none of the methods is reliable[10-12].

Digital radiography was most acceptable for this purpose due to its easy availability and affordability. But there is a possibility of error without its standardization that can appear due to rotation of the hip. The rotation of hip may lead to overestimation or valgization of NSA and in a similar way flexion of the hip can represent as underestimation or varization of the angle [13]. Thus, it requires positioning the hip in approximately 15-20 degrees of internal rotation to standardize the Antero-posterior (AP) radiograph. However, correct positioning is difficult to achieve in cases of trauma due to pain and also in cases of contractures, like in patients of cerebral palsy, osteoarthritis, etc. Due to these drawbacks of radiography, pre-operative measurements (size and shape) for a femoral component in custom-made prosthesis cannot be accepted as accurate. The Femoral neck-shaft angle can be accurately measured by using CT scan and MRI images. But their use was limited until now because of non-accessibility in many institutes and high-cost factor [14].

CT scan is superior to all other methods for assessment of proximal femur structure but the high dose of radiations is questionable and has ethical issues for use in healthy people or fertile aged women. MRI, on the other hand, does not have any radiation hazard and for this reason, it is best for analysing Neck shaft angle [15].

The modified neck- shaft angle (mNSA) is barely sensitive to the effects of rotation like the traditional NSA. This new method for measuring NSA was described by Christoph Kolja Boese et al in 2016 and they found it to be better and reliable than old methods [16].

Currently surgeries for proximal femur fractures and other diseases of hip have become very common and they use a variety of implants, like Dynamic Hip Screw, Dynamic condylar screw, the proximal femoral nail (PFN), angled blade plates and, all types of prosthesis that are used in hip arthroplasty. All these are manufactured according to the biomechanical consideration and the anthropometric data available for the western world. Furthermore, the appropriate use of the Neck-Shaft Angle (NSA) in the development of orthopaedic implants and prosthesis may have impact on the durability of implants and in getting good fixations[17-20]. The objective of the present research was to evaluate the modified femoral neck-shaft (mNSA) angle of the proximal Femur measured by MRI scan, and to determine any differences of these measurements according to the age and gender.

METHODS

This observational study was conducted at Teerthanker Mahaveer Medical College and Research Centre, Moradabad, India after getting approval from ethical committee, between 2018 to 2019. All participants above the age of 18years were included in the study while participants with any pathology of hip joint, any history of previous surgery around hip joint, deformity in hip, presence of orthopaedic implant around the hip joint or having any contraindications to MRI were excluded from the study. Participants were further grouped under 4 cohorts for analysis consisting of 50 scans (50 hips) in each : (I) males 18-60 years age, (II) males above 60years age, (III) females18-60years age, (IV) females above 60years age. All these participants underwent MRI of hip. Images were observed and evaluated by a single investigator on console. Modified Femoral Neck – shaft angle was measured as shown in Figure 1.

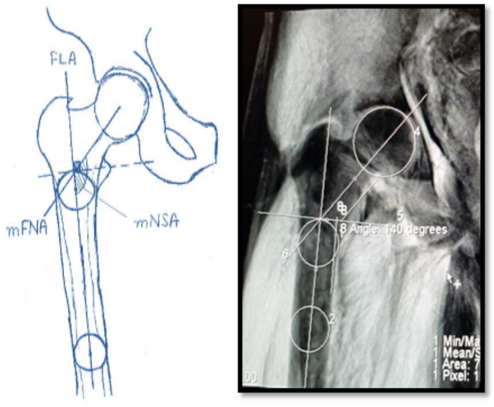

Figure 1: Diagram showing drawing of the circles and lines as defined on MRI. The intersection of Femoral long axis (FLA) and modified Femoral Neck Axis (mFNA) were used to make modified Femoral Neck-shaft angle (mNSA).

FLA (Femoral long axis): a line crossing the centre of two circles placed around the outer margins of the sub-trochanteric femur at 2 distinct positions: the centre of the upper circle was positioned at the lower boundary of the lesser trochanter and the lower circle was placed 2cm below the first, due to the end of the scan at this height.

The modified femoral neck axis (mFNA): the line connecting the centre of rotation and the FLA at the height of the apex of the Lesser Trochanter. Thus, a circle defined by three points around the margin of the femoral head was drawn, determining the centre of rotation.

A perpendicular to the FLA was drawn, cutting the apex of the Lesser Trochanter. **The Modified Femoral NSA (mNSA)** was defined as the angle between the FLA and the modified FNA (mFNA).

Statistical Analysis:

Data was analysed statistically by finding the mean, standard deviation and percentage of the parameters studied. The statistical software used for descriptive statistics was SPSS (version 20.0). The results of these parameters were compared between the cohorts studied and the results were correlated using appropriate statistical test - unpaired student *t*-test, one way and two way ANOVA tests. A value of $p \leq 0.05$ was considered significant.

RESULTS

Total of 200 participants (or 200 hips) were equally distributed among 4 age and gender wise cohort groups. The mean age of overall studied participants was 49.76 years (18 to 87years, SD 18.184years). Mean age of females and males were 50.45 years (18 to 83 years) and 49.07 years (18 to 89 years) respectively as shown in Table 1.

Table 1: Mean age of study cohorts.

Frequency (n)	MEAN AGE (years)	STANDARD ERROR OF MEAN	RANGE	STANDARD DEVIATION (SD)
200	49.76	1.286	69(18-87)	18.184

Gender based analysis:

The data was grouped by gender as shown in Table 2 and we observed that males (n= 100) had higher values of mean mNSA (149.93±6.61 degrees) than that of females (n=100) (145.78±5.71 degrees). This difference was found to be statistically significant (t=4.747, p<0.0001).

Table 2: Gender wise distribution of modified neck shaft angle (mNSA).

Gender Group	Frequency (n)	Mean mNSA (degrees)	t-value, p-value	Std. Deviation	Std. Error Mean (SEM)
Male	100	149.9300	t = 4.747*,	6.61839	.66184
Female	100	145.7800	p < 0.0001	5.71120	.57112

*independent student t-test

Age based analysis:

All the measured values were distributed among 2 groups with cut-off age of 60years as shown in Table 3. Out of the total 200 participants, the group of younger age participants (n= 100) (<60 years) had higher neck-shaft angle (148.32±6.65 degrees) than older (> 60years) ones (n = 100) (147.3900±6.35). But this difference was not statistically significant (t=1.011; p>0.05).

Table 3: Age wise distribution of modified neck shaft angle (mNSA)

Age Group	Frequency (n)	Mean mNSA (degrees)	t-value, p- value	Std. Deviation	Std. Error Mean (SEM)
Less Than 60 Years	100	148.32	t = 1.011*, p > 0.05	6.65283	.66528
More Than 60 Years	100	147.39		6.35784	.63578

*independent student t-test

Measurement data of all 4 cohorts is shown in table 4 showing mean, range and standard deviation of modified Neck shaft angle. Younger male participants (<60 years) had maximum value of mean mNSA (150.32±7.39 degrees) while minimum mean mNSA was found among older females (145.24±6.21 degrees). However the overall maximum mNSA was 166° in older male group and minimum angle was 129° in younger male group.

The measurement data frequency histogram is shown in Figure (2). The figure shows that out of 200 participants maximum participants had angles between 140 – 150° and minimum participants were in the range of 120-130° irrespective of age and gender.

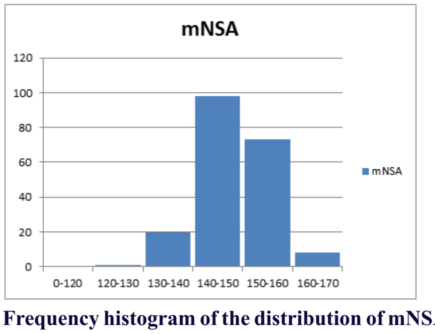

Figure 2: Frequency histogram of the distribution of mNSA in 200 hips.

Table 4: Analysis of modified neck shaft angle (mNSA) in the study cohorts based on gender and age - group.

AGE GROUP = <60, GENDER GROUP = MALE					
	N	Minimum	Maximum	Mean	Std. Deviation**
mNSA*	50	129.00	164.00	150.3200	7.39122
AGE GROUP = <60, GENDER GROUP = FEMALE					
	N	Minimum	Maximum	Mean	Std. Deviation
mNSA	50	136.00	156.00	146.3200	5.16045
AGE GROUP = >60, GENDER GROUP = MALE					
	N	Minimum	Maximum	Mean	Std. Deviation
mNSA	50	138.00	166.00	149.5400	5.79306
AGE GROUP = >60, GENDER GROUP = FEMALE					
	N	Minimum	Maximum	Mean	Std. Deviation

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mNSA	50	130.00	155.00	145.2400	6.21900
TOTAL RESULT					
mNSA	200	129.00	166.00	147.8550	6.50736

* modified Neck shaft angle , ** Standard deviation

Table 5 shows significant differences in between the paired males and females of age wise groups (< 0.0001) using two-way ANOVA test. But no statistically significant difference was found in mean neck-shaft angle according to the age variation (p>0.05).

Table 5: Gender and age wise relationship of modified neck shaft angle (mNSA) in study cohorts.

	Gender	Frequency (n)	Mean	Mean Difference	Standard Deviation	p - value**
Less than 60 years	Male	50	150.3200	4.0000	7.39122	p<0.0001
	Female	50	146.3200		5.16045	
More than 60 years	Male	50	149.5400	4.3000	5.79306	p<0.0001
	Female	50	145.2400		6.21900	
Total	Male	100	149.9300	4.1500	6.61839	p<0.0001
	Female	100	145.7800		5.71120	

* p = 0.290 (p > 0.05) for age groups (<60years and > 60 years). ** Two way ANOVA test

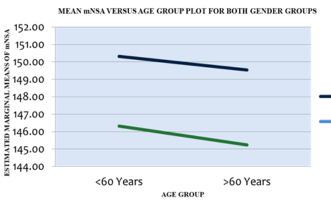

Figure 3: Mean mNSA versus Age groups

The trend of the mNSA in the studied 200 participants is shown in figure 3. The trend for both the genders was found to be same that is sloping downward from younger to older age. But the means of mNSA was higher for males compared to females for both younger and older age groups.

DISCUSSION

Many studies conducted on the measurement of femoral neck-shaft angle have shown variation in neck-shaft angle which is attributable to varying levels of activity, morphology, race, and lifestyle[17]. Since the neck-shaft angle affects the biomechanics of the hip, therefore, the goal of all hip-related surgeries is to restore the normal neck-shaft angle. This is also important in cases of hip arthroplasty where femoral components are designed with the proper knowledge of NSA [45]. In the present study, we made our focus to get the normal values of NSA with the help of a standardized technique using MRI and observing the differences according to age and gender since the data for Indian sub-population was lacking.

In this study, the mean modified neck-shaft angle for males was 149.93±6.61 degrees and for females, it was 145.78±5.71 degrees. The mean NSA for the 200 studied participants was 147.85±6.50 degrees. We found that the mean mNSA of males was significantly higher (p< 0.0001) than females. The average mean of mNSA for participants less than 60 years of age group was higher (148.32±6.65 degrees) than for participants of more than 60 years of age group (147.3900±6.35 degrees). This result was compared with different studies published in the literature as there was a wide variation of NSA among the different populations.

Boese CK et al (2016) did their study on 400 participants using CT scans and concluded that total mean modified NSA was 147^{o} which was comparable to the present study. But their study did not show any significant sex-based difference [16]. Nobel et al. measured the NSA among Americans, using the dry bone. The value of NSA was 124^{0}[20]. Rubin et al (1992), and Husmann et al (1997) did study among the European population by the radiographic method and they found mean NSA to be 122.9^{o} and 129.2^{o} respectively [37, 46]. Rawal et al (2012) and Roy et al (2014) did study among the Indian population by use of CT and radiograph respectively. They concluded that the mean NSA was 124^{0} and 130^{0} respectively [47,48].

Gilligan et al in his cadaveric study of 115 Chinese found that NSA was 127 degrees which is very lower than our present study. This difference in mean NSA may be attributable to different climatic and lifestyle patterns of the populations studied in our and Gilligan et al study. Gilligan et al concluded in his study that variations in climate, lifestyle, and latitude can affect NSA [42]. Saikia et al in their study among 104 people concluded that NSA in the northeast population of India was found to be 139.5^{o}[49].

According to a study done by AasisUnnanuntana et al the average NSA was higher in males compared to females which matches with our present study [50]. Parson et al studied dry bones of the English population and concluded that NSA was 126^{0}in males and 125^{0}in females[34]. Reikaraas et al (1982) also reported NSA values in males to be higher than females [36]. On the contrary Laville et al (1974) showed that NSA was greater in females compared to males [51]. Another study was done by Graham and Yarbrough (1968) among Indians that established higher NSA in males as compared to females [52]. Purkait R (1996) also found higher values of NSA in males (128) compared to females (125) by dry bone measurements [53].

We observed no significant difference in both males and females according to age (p > 0.05). This is similar to study of Shrestha R (2018) done on Nepalese participants. They revealed that NSA does not change significantly after 21 years of age [45].

Earlier to this study, many methods were being used for NSA measurements like dry bone measurement, radiography, ultrasound, and CT scan. These studies had limitations. A wide variation in measured NSA had been observed in various Indian literature like 123^{o} (Siwach et al, 2003) using dry bone and radiography to $139.5±7.5^{o}$ (Saikia et al, 2008) by using CT scan [18,49].

The present study used a clearly defined method for drawing the landmarks and making axis for measurement of a modified form of NSA using a non-invasive modality (MRI) which was highly reproducible. We used a large cohort of 200 adult Indian populations that covered both the genders and included a wide range of ages (18-87 years).

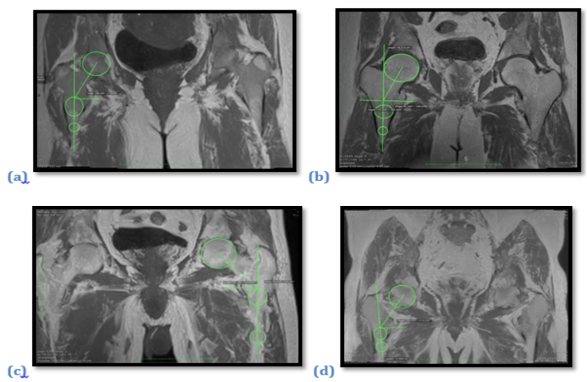

Figure 4: Coronal view of proximal Femur on MRI of (a) 40years old female participant with demonstration of modified femoral neck-shaft angle (mNSA) of left femur measured as 149^{o}. (b) 24 years old male participant with demonstration of modified femoral neck-shaft angle (mNSA) of left femur measured as 153^{o}. (c) 66years old female participant with demonstration of modified femoral neck-shaft angle (mNSA) of left femur measured as 135^{o}. (d) 64years old male participant with demonstration of modified femoral neck-shaft angle (mNSA) of right femur measured as 144^{o}.

CONCLUSION

From our study it can be concluded that gender based variation does exist in the studied population with the higher values of neck shaft angle in males as compared to females in any age group. However, this study did not establish any significant difference in the angles among the two age groups i.e. participants of less than 60yrs and more than 60yrs. The present study can be of use to orthopaedic surgeons for planning surgeries like osteotomies, to the biomedical engineers for designing implants and prosthesis corresponding to this ethnic group, to the forensic anthropologists to determine racial variation of the angle and also to the anatomists. It can be recommended from this study that MRI can be used as a standard method to measure NSA for the investigation of proximal femoral geometry. We also recommend for a multicentre study using this method for establishing normal values for a larger subset of population.

STRENGTH AND LIMITATIONS OF THE STUDY

The strength of our study was that the study included a large cohort of participants in the study (200 adults) of a variety of ages (18-87 years). Also, the modality used for study purposes was MRI which is least affected by anteversion and joint contractures and is also non-invasive for study in a healthy population.

The limitations of the study are that it did not include the paediatric population, the subset where hip-related surgeries for conditions like developmental dysplasia of the hip (DDH) are required for correction of hip biomechanics. Also MRI is an expensive technique that is not easily available. The present study did not take into account the side laterality, anteversion angle of femur, physical activity, height and weight of the participants which might affect the neck-shaft angles.

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