Correlation Between Anteversion and neck-Shaft Femoral Angles, For Designing Of Hip Prostheses

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Abstract: Background& Objective: Femoral neck anteversion angle (FNA) and neck-shaft angle (NSA) or inclination angle are important anatomic indicators in clinical orthopedics. Main aim of this study, is to determine correlation between FNA and NSA to prediction one of these parameters from other to designing of hip prostheses .Methods: Each femur was placed with the posterior surface of its condyles and greater trochanter touching a smooth horizontal surface (Kingsley and Olmsted method). For measurement of anteversion angle, Retrocondylar axis andfemoral neck axis were made with digital photography and with Digimizer software. For measurement of inclination angle, femoral neck axis and Diaphyseal axis were made with same manner. Results: 159 dried femora were studied. Average anteversion angle in degree for male was 12.17° (±6.83°) and in female was 15.14° (±9.17°). According to this study, in left male femur, for one degree increase in NSA, FNA grows 0.38°; in right male femur, for one degree increase in NSA, FNA grows 0.74°; in right female femur, for on degree increase in NSA, FNA grows 1.55°.Interpretation& Conclusion:In this research, we found that there is a meaningfulpositive relationship between FNA and NSA, to prediction on of them from the other. This relationship is seen in male femur (right and left) and Female femur (just right). [Ehsangolchini NJIRM 2016; 7(5): 25-32]

Key words: Anteversion angle, Neck-Shaft angle, Femur

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Introduction: The femoral neck in humans is an important functional modification after man attained erect bipedal posture(1). Geometric parameters of femoral neck are important for diagnosis and treatment of many disease of this body region.Femoral neck anteversion angle (FNA) and inclination angle (neck-shaft angle [NSA]) are important anatomic indicators in clinical orthopedics. These two parameters should be given full consideration during total hip arthroplasty (THA) to reduce the risk of postoperative dislocation. Additionally, it is reported that abnormal acetabularanteversion and femoral version participate in the etiogenesis of hip osteoarthritis, developmental dysplasia of the hip (DDH) and gluteal tendinopathy(2).FNA and NSA are two important parameters of femur anatomy in selection and designing of proper hip prostheses(3).

The femoral neck version angle can be defined as the angle formed by the femoral condyles plane (bicondylar plane) and a plane passing through the center of the neck and femoral head. If the axis of the neck inclines forward to transcondylar plane the angle of torsion is called anteversion, if it points posterior to the transcondylar plane it is called retroversion and if the axis of neck is in the same line of transcondylar plane it is known as neutral version. At birth, the normal anteversion angle is around 30°-40°, but this gradually reaches to approximately -25°-37° in an adult(4). Certain conditions such as cerebral palsy can lead to an increased angle because of muscle imbalance. Femoral retroversion can also occur as the result of an external rotation contracture of the hip secondary to reduced uterine space(5).

NSA or Inclination (6) isan angle between femoral neck axis and diaphyseal axis(7). This angle in birth time is about 160° and gradually diminished to reach about 110°-140° in an adult. This normal reduction in NSA, is dependent to weight bearing hip region and increasing in person movement.

Objective of this study was to determine correlation between FNA and NSA to prediction one of these parameters from other to designing of hip prostheses.Always should be appropriate correlation between FNA and NSA of hip prosthesis; absence of this correlation, results in discomfort and movement deficiency in patients.

Methods: This cross-sectional study was conducted at the Department of Anatomy, Medical Faculty, Tehran University of Medical Sciences, Tehran, Iran from October 2014 to May 2015. 159 dried adult human femora (unpaired), 81right (%50.9) and 78 left (%49.1), with 122 male type bones (%76.7) and 37 female type bones (%23.3) were studied. Broken bones, immature unossified (Children) bones, and bones with having deformities (e.g., bowing, malrotation) or malshaped by disease (e.g., osteoarthritis) were excluded.

Each femur was placed with the posterior surface of its condyles and greater trochanter touching a smooth horizontal surface (Kingsley and Olmsted method)(3).
For measurement of anteversion angle, first two axis was defined(Fig 1):

- Retrocondylar axis: this axis was a line drawn from the posterior surface of medical condyle to posterior surface of lateral condyle. Because posterior surface of two condyle was rested on surface (table), surface of table (horizontal plane) was corresponded with retrocondylar axis (F line).
- Femoral neck axis: for drawing this axis, two references points were defined in superior-horizontal view. These two references point were determined in this manner:

- First point: two horizontal lines (A and B lines) were drawn, each passing through the superior and inferior point of the head respectively.The line that connectssuperior and inferior most points of the head of femur, was defined C line. Middle point of C line, was defined as the first point.
- Second point: a line (D line) was drawn joining the narrowest part of anterior-posterior thickness of the neck. Middle point of D line, was defined as the second point.
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The line passing through these two references points (E line) represents femoral neck axis.

The angle formed between the retrocondylar axis and femoral neck, was measured as anteversion angle.

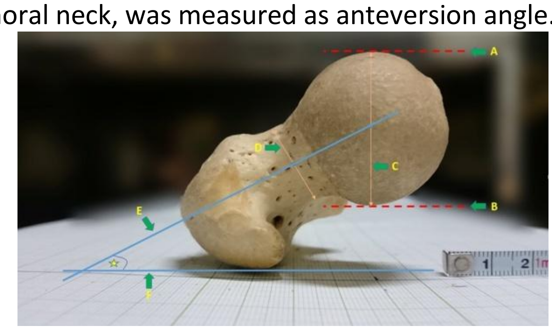


Figure 1: Femoral anteversion angle measurement method. Superior point line (A line);inferior point line (B line);a line that connects Anterior and posterior most points of the head of femur (C line);a line that joins the narrowest part of anterior-posterior thickness of the neck (D line);a line that passes through the middle points of C and D lines (E line) is represented femoral neck axis;surface of table (horizontal plane) was corresponded with retrocondylar axis (F line); the angle between E and F lines is measured as anteversion angle (Star sign).

For measurement of inclination angle, first two axes was defined(Fig 2):

- Femoral neck axis: for drawing this axis, two reference point was defined in anterior view. These two references point were determined in this manner:

- First point: two horizontal lines (A and B lines) were drawn, each passing through the superior and inferior most point of head respectively. Another line (C line) was drawn joining the superior and inferior most points of head of femur. Middle point of C line, was defined as first point.
- Second point: a line (D line) was drawn joining the narrowest part of superior-inferior thickness of the neck. Middle point of D line, was defined as the second point.

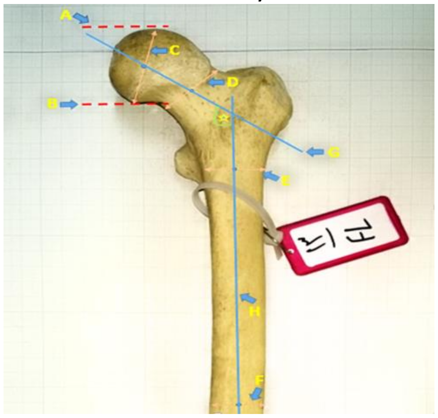
The line passing through these two references points (G line) represented femoral neck axis.

- Diaphyseal axis: for drawing this axis, two horizontal lines were drawn (E and F lines) in anterior view; line Eat proximal end of shaft where intertrochanteric line ends; line F, at midway of femoral length. The line passing through middle point these two lines (H line), represented diaphyseal axis.

The angle formed between the femoral neck axis and diaphyseal axis, was measured as inclination (neck-shaft) angle.

In this study for drawing axes of inclination angle, a photograph was taken from superior-horizontal view (for anteversion angle) and anterior view (for inclination angle) of bones. These photographs were delivered to Digimizer (version 4.3.0) software and according mentioned manners, the axes and angles were drawn and measured respectively.

Statistical analyses were performed using the SPSS 22 software (SPSS Inc.Chicago, IL). For finding of correlation between FNA and NSA, we used linear regression. Also Mean, Maximum, Minimum, SD and P-Value of Variables were analyzed.



- Figure 2: Femoral Inclination angle measurement method. superior most point line (A line); inferior most point line (B line); a line that connectsuperior and inferior most points of the head of femur (C line); a line that joins the narrowest part of superior-inferior thickness of the neck (D line); a line that passes through the middle points of C and D lines (G line) is represented femoral neck axis;a line at proximal end of shaft where intertrochanteric line ends (E line);a line at midway of femoral length (F line); a line passing through middle point these two lines (H line) is represented diaphyseal axis; the angle between H and G lines is measured as neck-shaft angle (Star sign).

Results: From 159 unpaired femora, right and left side distribution was 81 (%50.9) and 78 (%49.1) respectively. Out of them 122 (%76.7) are of male and 37 (%23.3) are of female.Average anteversion angle in degree for male was 12.17° (±6.83°) and in female was 15.14° (±9.17°) (p=0.03); with range of 0°-39.92°. Average anteversion in right side was 13.61° (±7.81°) and in left side was 12.07° (±7.13°) (p=0.19). Average inclination angle in degree for male was 125.51°(±4.94°) and in female was 126.29 (±4.72) (p=0.4); with range of 112.25°-134.99°. Average inclination in right side was 126.02° (±4.86°) and in left side was 125.35° (±4.92°) (p=0.38).Categories of distribution of FNA and NSA were written in Table 1 and Table 2 respectively.

Table 1: Categories of distribution of FNA

Subtype	Left femur		Right femur	
	Frequency	%	Frequency	%
0°-5.9°	14	17.7	12	15
6°-15.9°	40	50.6	36	45
16°-25°	22	27.8	28	35
>25°	3	3.8	4	5
Total	79	100	80	100

Table 2: Categories of distribution of NSA

Subtype	Left femur		Right femur	
	Frequency	%	Frequency	%
<115°	1	1.3	2	2.5
115°-120°	7	8.9	5	6.3
120.1°-125°	30	38	26	32.5
125.1°-130°	29	36.7	31	38.8
130.1°-135°	1	13.9	15	18.8
>135°	1	1.3	1	1.3
Total	79	100	80	100

According to table 3, outcomes of linear regression analysis showed Femoral Version angle associates with Neck-Shaft angle in left male bone (p=0.029), right male bone (p<0.001) and right female bone (p=0.002). This analysis showed that FNA hasn't meaningful relationship with NSA in left female bone (P=0.1). According to this, in left male femur, for one degree increase in NSA, FNA grows 0.38° (coefficient=0.38)(Fig 3); in right male femur, for one degree increase in NSA, FNA grows 0.74° (coefficient=0.74)(Fig 4); in right female femur, for on degree increase in NSA, FNA grows 1.55° (coefficient=1.55)(Fig 5). For convenience in estimation of FNA from NSA, we designed threeformulae:

Female right

FNA = -181.5 + 1.55 NSA

Male left

FNA = -36.14 + 0.38 NSA

Male right

FNA = -80.65 + 0.744 NSA

Table 3: Linear regression analysis of FNA and NSA

		NSA coefficients		P-value	R^2adj
Female	Left	Constant	-68.15	0.176	0.108
		B	0.655	0.107	
	Right	Constant	-181.5	0.003	0.415
		B	1.55	0.002	
Male	Left	Constant	-36.14	0.095	0.062
		B	0.38	0.029	
	Right	Constant	-80.65	<0.001	0.277
		B	0.744	<0.001	

Figure 3: Relationship between FNA and NSA in left male femur

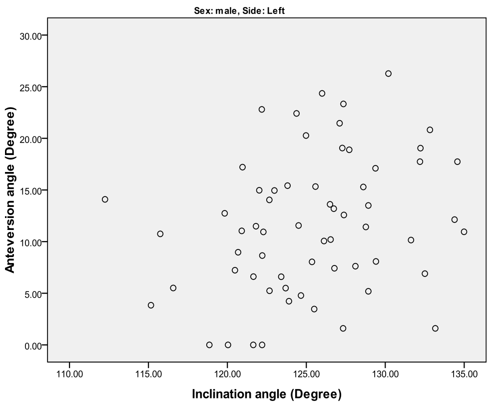


Figure 4: Relationship between FNA and NSA in right male femur

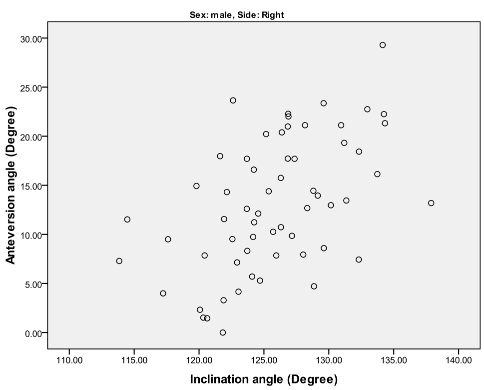
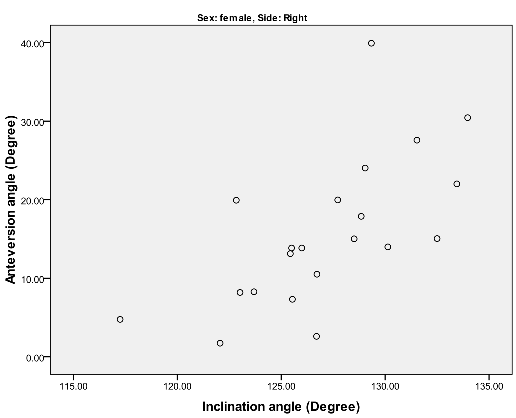


Figure 5: Relationship between FNA and NSA in right female femur



Discussion: Neck shaft angle and anteversion of the femur are common measurements for studies involving correlations with congenital hip dislocation, slipped capital femoral epiphysis, risk of osteoarthritis, femoral neck fracture, and instability of the hip. They are also used for diagnosing pediatric in-toing or out-toing gait, as well as for patient selection and surgical planning for derotation osteotomy of the femur and total hip replacement(8). Femoral anteversion an neck-shaft angle in normal populations varies tremendously(9). We found that FNA and NSA in Iranian normal population adults are independent to laterality (respectively: p=0.19 and p=0.38). Mean of FNA and NSA in female were greater than male. In addition, we found that there were meaningful relationship between FNA and NSA in left male femur, right male femur and right female femur but not in left female femur.In Table 4, we collected FNA amount in many population. Accordingly, Mean values of FNA are 12.95° (American), 11.9° (British), 13.2° (Norwegian), 12.6° (Netherland), 9.73° (India), Thai (11.37°), Korean (13.75°), 14.8° (Japanese) and 10.62° (Chinese). In this study, mean valueof FNA in Iranian population is 13.65° (F: 15.14° and M: 12.17°).Right vs. left side variation for the femoral neck anteversion angle was non-significant in our study, similarWaliUllah Khan research(3). Jiang et al mentioned that no difference in laterality of FNA(2).Like this current study, Wrigth et al reported that females had greater FNA than males ($P<0.05$) in Nederland population(10). Rawal et al reported that females had greater FNA than males (P=0.001) in Indian's FNA(11). However, Koerner et al reported no sex difference (P=0.56) in American's FNA(12). Similarly, Reikeras et al reported no sex difference ($P>0.05$) in Norwegian's FNA(13). Also, Maruyama et al reported no sex difference (p=0.95) in Japanese's FNA(14). Umebese et al reported no sex difference in Nigerian's FNA(15).

In Table 5, we collected NSA amount in many population. Accordingly, Mean values of NSA are 129.57° (American), 131° (Canadian), 127.4° (British), 127.7° (Norwegian), 125.3° (French), 124.2° (Netherland), 124.85° (Turkish), 121.9° (South Africa), 121° (Nigerian), 134° (Pakistani), 127.54° (Indian), 126° (Japanese) and 130.65° (Chinese). In this study, mean value of NSA in Iranian population is 125.9° (F: 126.29° and M: 125.51°). A previous study, reviewed a global NSA database comprising over 8000 femora representing 100 human groups. Results from the analyses showed an average NSA for modern humans of 127° (markedly lower than the accepted value of 135°); there was no sex difference, no age-related change in adults, but possibly a small lateral difference which could be due to right leg dominance(16). In our study, mean value of NSA angle in Iranian population is 1.1° lesser than global value.

There are very few studies about correlation between FNA and NSA. In this study, we found this correlation.

In a last study, a week negative correlation between FNA and NSA was reported (coefficient: - 0.07) which was not significant. O Reikeras in his study on 48 cadavers also found poor correlation (coefficient: 0.26) between FNA and NSA(17).In our study, we found positive stronger and sex-based and laterality-based correlation between FNA and NSA.

Table 4: Comparison of foreign FNA studies (10-15, 17-30)

No	Authors	Year	Sample size	Population	Method	FNA(mean)
1	Pick	1914	152	American	Dry bone-Mechanical	14°
2	Kingsley	1948	630	American	Dry bone-Mechanical	8°
3	FT.Hoaglund	1980	55	American	Dry bone-Mechanical	8.5
4	PAToogood	2009	375	American	Dry bone-Digital Photo	9.7°
5	Bargar	2010	46	American	CT	13.8°
6	K Kulig	2010	28	American	Ultrasound	20.7°
7	K Kulig	2010	28	American	MRI	19°
8	Botser	2012	129	American	CT	15.9°
9	Botser	2012	129	American	MRI	7°
10	Parsons	1912	266	British	Dry bone-Mechanical	15.3°
11	HDAtkinson	2010	100	British	CT	8.5°
12	Reikeras	1982	96	Norwegian	Dry bone-Mechanical	10.4°
13	Braten	1992	200	Norwegian	Ultrasound	16°
14	Wright	2014	60	Netherland	CT	12.6°
15	RC Siwach	2003	150	Indian	X-ray	13.68°
16	AVMaheshwari	2004	62	Indian	Clinical	13.0°
17	AK Jain	2005	72	Indian	CT	7.4°
18	AK Jain	2005	138	Indian	X-ray	11.5°
19	AK Jain	2005	138	Indian	Clinical	13.1°
20	AK Jain	2005	300	Indian	bone-Mechanical	8.1°
21	Nagar M	2006	182	Indian	bone-Mechanical	13.6°
22	KC Saikia	2008	92	Indian	CT	20.4°
23	AR Shrikant	2009	288	Indian	Dry bone-Mechanical	8.7°
24	A Zalawadia	2010	92	Indian	Dry bone-Mechanical	12.4°
25	AVMaheshwari	2010	172	Indian	CT	8°
26	AnkurZalawadia	2010	92	Indian	Dry bone-Mechanical	12.4°
27	Rawal	2012	98	Indian	CT	10.9°
28	Mahaisavariya	2002	108	Thai	CT	11.37°
29	Lee	2006	24	Korean	CT	18.5°
30	Yun	2013	112	Korean	CT	9°
31	Sugano	1998	30	Japanese	CT	19.8°
32	Maruyama	2001	200	Japanese	Dry bone-Mechanical	9.8°
33	Jiang	2015	466 (paired)	Chinese	CT	10.62°
34	Caetano	2007				

Table 5: Comparison of foreign NSA studies (10, 11, 13, 14, 16, 17, 24, 29, 31-34)

No	Authors	Year	Sample size	Population	Method	NSA(mean)
1	FTHoagland	1980	55	American	Dry bone-Mechanical	135°
2	Nobel	1988	200	American	Dry bone-Mechanical	124.7°
3	Trinkaus	1993	55	American	Dry bone-Mechanical	129.4°
4	PAToogood	2008	375	American	Dry bone-Digital Photo	129.2°
5	Yoshioka	1987	32	Canadian	Dry bone-Mechanical	131°
6	Parsons	1924	134	British	Dry bone-Mechanical	126.3°

7	HDAtkinson	2010	100	British	CT	128.5°
8	O Reikeras	1982	96	Norwegian	Dry bone-X- ray	127.7°
9	Rubin	1992	32	French	X- ray	122.9°
10	Husmann	1997	310	French	X- ray	129.2°
11	M Lequesne	2004	446	French	X- ray	132.8°
12	Wright	2014	60	Netherland	CT	124.2°
13	Oguzo	1996	50	Turkish	Dry bone-Mechanical	124.85°
14	Macho	1991	361	South African	Dry bone-Mechanical	121.9°
15	PFUmebese	2005	116	Nigerian	X- ray	121°
16	M Inam	2011	100	Pakistanian	X- ray	134°
17	B Isaac	1997	171	Indian	Dry bone-Mechanical	126.7°
18	RC Siwach	2003	150	Indian	Dry bone-Mechanical	123.5°
19	RC Siwach	2003	150	Indian	Dry bone–X- ray	123°
20	KC Saikia	2008	92	Indian	CT	139.5°
21	TRDeshmukh	2010	77	Indian	X- ray	131.5°
22	Amith Ramos	2012	171	Indian	Dry Bone Computer Assisted	121.2°
23	Rawal	2012	98	Indian	CT	124.42°
24	Roy	2014	204	Indian	X- ray	130.57°
25	K Kiyono	1928	46	Japanese	Dry bone-Mechanical	124.6°
26	Yamaguchi	1993	60	Japanese	X- ray	128.4°
27	Sugano	1998	30	Japanese	X- ray	126°
28	Maruyama	2001	200	Japanese	Dry bone-Mechanical	125°
29	FTHoagland	1980	51	Chinese	Dry bone-Mechanical	136.2°
30	Liang J	2009	56	Chinese	CT	126.2°
31	Gilligan	2013	115	Chinese	Dry bone-Mechanical	127.2°
32	Jiang	2015	466 (paired)	Chinese	CT	133.02°

Conclusions: In this research, we found that there is a meaningful relationship between FNA and NSA, to prediction on of them from the other. This relationship is seen in male femur (right and left) and Female femur (just right). The relationship is presented in three formulae. There is no relationship in left female femur in our study. Additionally, based on current data, no significant difference have been identified in laterality dependence of FNA and NSA. Our finding is applicable for selection and designing hip prostheses and other orthopedic features because always should be appropriate correlation between FNA and NSA of hip prosthesis; absence of this correlation, results in discomfort and movement deficiency in patients.

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