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Femoral Version, Neck-Shaft Angle, and Acetabular Anteversion in Chinese Han Population

A Retrospective Analysis of 466 Healthy Adults

Nan Jiang, MD, Lin Peng, MD, Mohammed Al-Qwbani, MD, Guo-Ping Xie, MD, Qin-Meng Yang, MM, Yu Chai, MD, Qing Zhang, MD, and Bin Yu, MD

Abstract: Anatomic data regarding femoral version, neck-shaft angle, and acetabular anteversion are still limited in Chinese Han adult population. The aim of this study was to investigate the effects of age, sex, and body laterality on the 3 important anatomic indicators in Chinese Han healthy adults.

Measurements were performed independently by 3 experienced observers using the picture archiving and communication system (PACS) in healthy adults who had received imaging tests of the femur and acetabulum between January 2009 and October 2014. Relevant data were measured and analyzed.

A total of 466 adults (353 males and 113 females) were included. The mean femoral version, neck-shaft angle, and acetabular anteversion for all were 10.62, 133.02, and18.79, respectively. Age-based analysis showed that adults younger than 60 years had a significantly higher neck-shaft angle ($P < 0.001$) but a significantly lower acetabular anteversion ($P < 0.001$) than those older than 60 years. Sex-based analysis revealed that females had significantly higher values of femoral version ($P < 0.001$) and acetabular anteversion ($P < 0.001$) than males. Laterality-based analysis found the left side had a significantly lower acetabular anteversion ($P < 0.001$) than the right side. Outcomes of multiple linear regression analysis indicated that femoral version may be associated with sex ($P < 0.001$) but not age ($P = 0.076$) or laterality ($P = 0.430$), neck-shaft angle may be associated with age ($P < 0.001$) but not sex ($P = 0.378$) or laterality ($P = 0.233$), and acetabular anteversion may be associated with age ($P < 0.001$) and sex ($P < 0.001$) but not laterality ($P = 0.060$).

In this representative Chinese cohort, neck-shaft angle may decrease, whereas acetabular anteversion may increase with age, females may have higher values of femoral version and acetabular anteversion than males, and the right body side may have a higher value of acetabular anteversion than the left side.

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Abbreviations: aBMD = area bone mineral density, CT = computer tomography, DDH = developmental dysplasia of the hip, FAI = femoroacetabular impingement, GTPS = greater trochanteric pain syndrome, LEA = lower extremity alignment, MRI = magnetic resonance imaging, PACS = picture archiving and communication system, PFG = proximal femoral geometry, THA = total hip arthroplasty.

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From the Department of Orthopaedics and Traumatology (NJ, LP, MAQ, G-PX, Q-MY, YC, QZ, BY); and Guangdong Provincial Key Laboratory of Bone and Cartilage Regenerative Medicine, Nanfang Hospital, Southern Medical University, Guangzhou, P.R. China (NJ, LP, MAQ, G-PX, Q-MY, YC, QZ, BY).
Correspondence: Bin Yu, Nanfang Hospital, Guangzhou, Guangdong Province 510515, P.R. China (e-mail: smuyubin@163.com).
JN and PL contributed equally to this study.
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INTRODUCTION

Femoral version, neck-shaft angle, and acetabular anteversion are important anatomic indicators in clinical orthopedics. Femoral version and acetabular anteversion should be given full consideration during total hip arthroplasty (THA) to reduce the risk of postoperative dislocation.[1,2] Additionally, it is reported that abnormal acetabular anteversion and/or femoral version participate in the etiogenesis of hip osteoarthritis,[3,4] developmental dysplasia of the hip (DDH),[5,6] and gluteal tendinopathy.[7] Femoral neck-shaft angle, defined as an intersection angle by proximal femoral shaft axis and femoral neck axis, is another clinically significant parameter of proximal femoral geometry (PFG). Recent studies[8,9] indicate that a greater neck-shaft angle may increase the risk of proximal femoral fracture. It is found that a lower neck-shaft angle may result in elevated risk of greater trochanteric pain syndrome (GTPS) in females.[10] Therefore, on one hand, as possible pathogenic indicators of some hip disorders, the 3 parameters should be noted during hip surgeries; on the other hand, identifying normal ranges of the parameters and their influencing factors may help surgeons perform hip surgeries better and predict the risk of hip disorders or injury.

Data derived from plenty investigations of PFG were varied because they might have been affected by many factors, such as ethnicity, age, sex, body side, measurement methods, even climate, clothing, and lifestyle.[11] In particular, ethnicity has been proved as one of the most important factors accounting for the variations. Currently, most PFG studies were performed in America,[12–15] Europe,[16,17] and other Asian countries like Japan,[2,18] Korean,[1,19] India,[20] and Thailand.[21] Although several similar studies[11,22,23] were conducted in Chinese population, their sample sizes were limited. Additionally, analysis is insufficient regarding the effects of age, sex, and body laterality on the PFG parameters. Therefore, currently limited PFG information in Chinese population necessitated an updated report with a larger sample size and stratified analysis by age, sex, and body laterality.

The aim of the present study was to investigate characteristics of femoral version, neck-shaft angle, and acetabular anteversion in Chinese Han healthy adults. We sought to compare the 3 parameters between 2 age groups with cutoff age of 60 years, sexes and literalities; report the rates of femoral retroversion, coxa valgus, and coxavara for all as well as for both stratified analysis by age, sex, and laterality.

PATIENTS AND METHODS

Study Design, Setting, and Data Source

The present study, designed as a retrospective analysis of femoral version, neck-shaft angle and acetabular anteversion in Chinese Han healthy adults, was conducted in Nanfang Hospital, affiliated to Southern Medical University, a tertiary medical center in Guangzhou, South China. Images of the participants who underwent computer tomography (CT) and plain radiograph tests of the femur and acetabulum were initially screened in picture archiving and communication system (PACS). Further eligibility assessment was performed based on the following inclusion and exclusion criteria. Time limit was set from January 1, 2009 to October 31, 2014. Ethical approval and written consents from the participants were waived due to the retrospective design of the present study. However, their personal information were anonymized and de-identified before analysis.

Inclusion and Exclusion Criteria

Inclusion criteria of the study participants were Chinese Han adults, eligible and adequate imaging data for measurement, and absence of previous disorders that might affect measurements of the parameters. Exclusion criteria included: foreigners or non-Chinese Han population; incomplete imaging data; and previous fracture, arthritis, tumor, deformity, or surgery on the proximal part of the femur or acetabulum. If only one body side was available and eligible for measurement, this single side was also included for measurement.

Measurement Performance and Methods

Measurements of femoral version, neck-shaft angle, and acetabular anteversion were performed independently by 3 experienced observers. If there were any discrepancies of >5 degree between any of the 2 observers, measurements were performed by both of them again. The average values were used for statistical analysis.

Femoral version was measured using the Weiner method,[24] by superimposing outcomes of the femoral neck axis and distal femoral condylar axis. Neck-shaft angle measurement, performed in standard anterior-posterior X-rays of the proximal femur or pelvis, was generated by the intersection angle between the femoral neck axis and proximal femoral shaft axis.[25] Acetabular anteversion, defined as the angle formed by a line between the anterior and posterior acetabular ridge and a reference line perpendicular to a line between the posterior pelvic margins at the level of the sciatic notch,[22] was measured on axial CT images through the acetabular center.

Statistical Analysis

Statistical analysis was conducted using the SPSS 17.0 software (SPSS Inc, Chicago, IL). Continuous data were presented as the mean and standard deviation. Dichotomous data were revealed as percentages. Two independent-samples *t* test was performed to evaluate the differences between 2 age groups and sexes. Paired-samples *t* test was taken to compare differences between the 2 body lateralities of the participants with available data of the both sides. Chi-square test was used to assess the differences in dichotomous variables. Multiple linear regression analysis was conducted to investigate the possible association of age, sex, and laterality with femoral version, neck-shaft angle, and acetabular anteversion separately. Statistically significant difference was defined as P value of <0.05.

RESULTS

Demographics

A total of 466 patients (353 males and 113 females) were included for measurement. The average age for all was 62.44 ± 18.72 years (range, 18–93 years). The mean age for males and females was 61.39 ± 18.18 years (range, 18–91 years) and 65.72 ± 20.04 years (range 18–93 years).

Primary Outcomes

Measurement Outcomes for All

The average values of femoral version, neck-shaft angle, and acetabular anteversion for all were 10.62 ± 9.02 (range, −15.66 to 39.12), 133.02 ± 4.49 (range, 118.74–143.15), and 18.79 ± 5.30 (range, 4.46–34.74), respectively.

Age-Based Analysis

All measurement data were divided into 2 groups with cutoff age of 60 years. As shown in Table 1, participants younger than 60 years had a significantly higher neck-shaft angle (133.97 vs 132.42, $P < 0.001$), but a significantly lower acetabular anteversion (17.79 vs 19.39, $P < 0.001$) than those older than 60 years. Additionally, no significant difference was found regarding femoral version between the 2 age groups ($P = 0.849$). Moreover, subgroup analyses sorted by sex and body laterality were in accordance with the above outcomes (Table 1).

Sex-Based Analysis

In the stratified analysis by sex (Table 2), females had significantly higher values of femoral version (14.76 vs 9.31, $P < 0.001$) and acetabular anteversion (20.44 vs 18.27, $P < 0.001$) than males. Additionally, no significant sex difference was found in neck-shaft angle ($P = 0.234$). Furthermore, subgroup analyses by age and body laterality also supported the above outcomes (Table 2).

Laterality-Based Analysis

In the analysis by body laterality (Table 3), outcomes revealed no significant differences regarding femoral version ($P = 0.175$) and neck-shaft angle ($P = 0.050$) between the 2 lateralities in addition to a statistically higher acetabular anteversion in the right side of body (19.10 vs 18.43, $P < 0.001$). However, not all the outcomes of subgroup analysis sorted by age and sex were in agreement with the above results. First, adults older than 60 years had a significantly higher femoral version at the left side (11.29 vs 10.19, $P = 0.012$). Second, females had a significantly greater neck-shaft angle at the left side (133.22 vs 132.16, $P = 0.027$). Third, although the right laterality had a higher acetabular anteversion than the left laterality for all, no significant difference was found between

TABLE 1. Femoral Version, Neck-shaft Angle and Acetabular Anteversion for all, for Sexes, and Lateralities by Age

	Age <60 Years		Age ≥60 Years		
Items	**No.**	**Values (M ± SD), degree**	**No.**	**Values (M ± SD), degree**	***P***
Femoral version	328	10.54 ± 9.31	557	10.66 ± 8.85	0.849
Males	269	9.28 ± 8.61	404	9.33 ± 8.58	0.948
Females	59	16.27 ± 10.26	153	14.18 ± 8.62	0.136
Left side	164	10.16 ± 9.22	280	11.20 ± 9.03	0.247
Right side	164	10.92 ± 9.42	277	10.11 ± 8.64	0.361
Neck-shaft angle	296	133.97 ± 4.28	466	132.42 ± 4.52	<0.001
Males	239	134.02 ± 4.40	342	132.51 ± 4.48	<0.001
Females	57	133.76 ± 3.75	124	132.17 ± 4.64	0.025
Left side	145	134.22 ± 4.22	237	132.58 ± 4.35	<0.001
Right side	151	133.73 ± 4.33	229	132.25 ± 4.70	0.002
Acetabular anteversion	343	17.79 ± 4.93	568	19.39 ± 5.43	<0.001
Males	280	17.47 ± 4.81	415	18.82 ± 5.41	0.001
Females	63	19.23 ± 5.26	153	20.94 ± 5.19	0.029
Left side	170	17.42 ± 4.79	285	19.08 ± 5.41	0.001
Right side	173	18.16 ± 5.06	283	19.70 ± 5.44	0.003

M ± SD = mean ± standard deviation.

the 2 sides in females (20.25 vs 20.85, $P = 0.131$). It requires more studies to certify whether these variances have clinical relevance or just in a statistical manner.

Multiple Linear Regression Analysis With Age, Sex, and Laterality as Covariates

Outcomes of multiple linear regression analysis showed that femoral version might be associated with sex ($P < 0.001$) but not age ($P = 0.076$) or laterality ($P = 0.430$), neck-shaft angle might be associated with age ($P < 0.001$) but not gender ($P = 0.378$) or laterality ($P = 0.233$), and acetabular anteversion might be associated with age ($P < 0.001$) and sex ($P < 0.001$) but not laterality ($P = 0.060$).

Secondary Outcomes

Rates of Femoral Retroversion, Coxa Valgus, and Coxavara

The rates of femoral retroversion (femoral version <0), coxa valgus (neck-shaft angle >140), and coxavara (neck-shaft angle <110) for all were 11.30% (100/885), 3.80% (29/762), and 0%, respectively.

In the stratified analyses by age, sex, and laterality, no statistical differences were found regarding femoral retroversion rate (under 60 years vs over 60 years: 12.20% vs 10.77%, $P = 0.518$) or coxa valgus rate (under 60 years vs over 60 years: 5.07% vs 3.00%, $P = 0.147$) between 2 age groups. Additionally, males had a significantly higher femoral retroversion rate than females (13.52% vs 4.24%, $P < 0.001$). However, there was no significant sex difference regarding coxa valgus rate (4.48% vs 1.66%, $P = 0.084$). Furthermore, no significant differences were identified between the left and right sides of body regarding femoral retroversion rate (11.04% vs 11.56%, $P = 0.804$) or coxa valgus rate (4.45% vs 3.16%, $P = 0.351$).

DISCUSSION

Femoral version, neck-shaft angle, and acetabular anteversion are important PFG indicators during hip surgeries. Moreover, abnormal values of the above 3 parameters may

TABLE 2. Femoral Version, Neck-shaft Angle, and Acetabular Anteversion for Different Age Groups, for Lateralities by Sex

	Males		Females		
Items	**No.**	**Values (M ± SD), degree**	**No.**	**Values (M ± SD), degree**	***P***
Femoral version	673	9.31 ± 8.58	212	14.76 ± 9.13	<0.001
Age <60 years	269	9.28 ± 8.61	59	16.26 ± 10.26	<0.001
Age ≥60 years	404	9.33 ± 8.58	153	14.18 ± 8.62	<0.001
Left side	340	9.60 ± 8.61	104	14.79 ± 9.59	<0.001
Right side	333	9.01 ± 8.57	108	14.72 ± 8.71	<0.001
Neck-shaft angle	581	133.13 ± 4.51	181	132.67 ± 4.43	0.234
Age <60 years	239	134.02 ± 4.40	57	133.76 ± 3.75	0.686
Age ≥60 years	342	132.51 ± 4.48	124	132.17 ± 4.64	0.481
Left side	292	133.21 ± 4.45	90	133.17 ± 4.11	0.946
Right side	289	133.05 ± 4.57	91	132.18 ± 4.70	0.117
Acetabular anteversion	695	18.27 ± 5.22	216	20.44 ± 5.26	<0.001
Age <60 years	280	17.47 ± 4.81	63	19.23 ± 5.26	0.010
Age ≥60 years	415	18.82 ± 5.41	153	20.94 ± 5.19	<0.001
Left side	349	17.93 ± 5.14	106	20.21 ± 5.24	<0.001
Right side	346	18.62 ± 5.27	110	20.67 ± 5.30	<0.001

M ± SD = mean ± standard deviation.

TABLE 3. Femoral Version, Neck-shaft Angle and Acetabular Anteversion for Different Age Groups, for Sexes by Laterality

		Left Side	Right Side	
Items	**Paired No.**	**Values (M ± SD), degree**	**Values (M ± SD), degree**	***P***
Femoral version	424	10.93 ± 9.13	10.41 ± 8.85	0.175
Age <60 years	156	10.32 ± 9.26	10.80 ± 9.22	0.509
Age ≥60 years	268	11.29 ± 9.05	10.19 ± 8.63	0.012
Males	324	9.68 ± 8.59	9.10 ± 8.52	0.187
Females	100	15.01 ± 9.67	14.66 ± 8.57	0.670
Neck-shaft angle	365	133.22 ± 4.37	132.79 ± 4.65	0.050
Age <60 years	143	134.26 ± 4.17	133.70 ± 4.38	0.097
Age ≥60 years	222	132.56 ± 4.38	132.20 ± 4.73	0.223
Males	280	133.22 ± 4.46	132.98 ± 4.59	0.327
Females	85	133.22 ± 4.10	132.16 ± 4.80	0.027
Acetabular anteversion	445	18.43 ± 5.21	19.10 ± 5.38	<0.001
Age <60 years	168	17.36 ± 4.79	18.12 ± 5.10	0.007
Age ≥60 years	277	19.08 ± 5.35	19.70 ± 5.46	0.010
Males	342	17.88 ± 5.07	18.58 ± 5.27	0.001
Females	103	20.25 ± 5.28	20.85 ± 5.39	0.131

M ± SD = mean ± standard deviation.

be associated with hip disorders like femoroacetabular impingement (FAI), hip osteoarthritis, and fractures. Therefore, identification of their normal ranges and possible influencing factors in healthy population can benefit clinical orthopedics. To provide more detailed and convincing PFG data in Chinese population, the present study in a larger cohort of Chinese Han healthy adults investigated the effects of age, sex, and body laterality on the 3 PFG parameters. Our measurements revealed that neck-shaft angle decreased, whereas acetabular anteversion increased with age, females had higher values of femoral version and acetabular anteversion than males, and the right side of body had a higher acetabular anteversion than the left side.

We found that femoral version in Chinese healthy adults was associated with sex but not age or laterality. In other words, females had a significantly higher femoral version than males. According to Nguyen and Shultz,[26] heredity and behavioral factors (eg, sitting in the ''reverse tailor's'' position, frequent in-toe belly sleeping) may contribute to greater femoral version in females. As a parameter of PFG and lower extremity alignment (LEA), femoral version plays an important role in lower extremity function. Understanding the sex difference in femoral version may help better clarify its role as a potential risk factor of injury, though definite relationship has not been established between the 2 aspects.[26]

Previous reports of femoral version were mainly from Americans,[12–15,27] Europeans,[16,17,23,28,29] Asians,[1,2,18–21,23,30] and Africans[31] (Table 4). The average values of femoral version reported for the 4 populations ranged from 8.02[12] to 15.9,[14] 10.4[16] to 24.7,[29] 9.0[1] to 19.8[18] and 28 (single report),[31] respectively. In a current measurement of the largest number of American cadavers, Kingsley et al[12] found similar values between sexes and body lateralities. Similarly, Koerner et al[27] also reported no sex difference ($P = 0.56$) in Americans. However, inconsistency existed regarding the femoral version between sexes in European and Asian populations. Reikeras et al[16] identified no sex difference ($P > 0.05$) in 48 Norwegians. But Wright et al[17] indicated that females had a statistically greater value than males ($P < 0.05$) in 60 Netherlanders. Similarly in Asian, Maruyama et al[2] showed no significant sex difference in 100 Japanese ($P = 0.954$), consistent with what reported by Sugano et al.[18] However, in a cohort of 60 Indians, Rawal et al[20] found a significantly higher value of femoral version in females than in males ($P = 0.001$). A single study[31] based on 116 Nigerians revealed no significant difference between the two sexes. Therefore, ethnicity and geography may be another factors accounting for the variations of femoral version in addition to sex.

As another important parameter of PFG, the value of neck-shaft angle is probably associated with age but not sex or laterality in Chinese Han population. As revealed clearly in Table 1, adults younger than 60 years had a significantly greater neck-shaft angle than those older than 60 years. In other words, femoral neck-shaft angle may decrease with age, which is in accordance with a recent study,[32] investigating the effects of growth and aging on proximal femoral bone in Chinese females. We think this is probably because area bone mineral density (aBMD) gradually decreases with age, resulting in gradually decreased support strength from the proximal femur. Therefore, just as Wang et al[32] indicated, both deterioration of aBMD and inadequate compensatory change in bone geometry account for the increased risk of fractures in elderly, especially for females.

Similar to femoral version, femoral neck-shaft angle is also affected by many factors. In a recent study based on a global neck-shaft angle database of 8271 femora, Gilligan et al[11] indicated that sex, age, body laterality, climate, clothing, and lifestyle were potential sources of variation for neck-shaft angle. They also found that the average value of neck-shaft angle for all was about 127 degree, with 130 degree, 126 degree, and 125 degree for populations in Pacific, Europe, and America. As shown in Table 5,[2,11,16–18,20,21,23,25,29,30,33,34] the mean neck-shaft angle for Americans, Europeans, and Asians ranged from 124.7 degree (single study),[33] 122.9[34] to 129.2,[29] 124.42[20] to 130.57,[25] respectively. Although most of the published studies reported no significant difference between sexes,[2,11,20,25] their stratified analysis for sex difference revealed that males tended to have a higher value of neck-shaft angle than females, which is supported by the present study. Additionally, we are also in agreement with the report by Hoaglund et al[23] in HK Chinese. They found the average neck-shaft angles for males and females were 135 and 134, quite similar to our measurements of 133.13 and 132.67, respectively. However, Gilligan et al[11] in a cadaveric study of 115 Chinese showed that the mean neck-shaft angle was 127,

TABLE 4. Previous Reports Regarding Outcomes of Femoral Version for All, for Sexes, and Body Lateralities

Study and Year	Specimen or Case No.	Ethnicity	Population	Method	Age (M/M ± SD) (Range), years	Value for all (M/M ± SD) (Range)	Sex difference (M/M ± SD) (Range)	Laterality difference (M/M ± SD) (Range)
Kingsley et al, 1948[12]	630	NA	American	Cadaver	>18	8.021 (−20 to 38)	M: 7.94 (−17 to 33.5) F: 8.11 (−20 to 38)	L: 7.47 (−17 to 38) R: 8.54 (−20 to 33.5)
Toogood et al, 2008[13]	375	Mixed	American	Cadaver	44 (18 to 89)	9.73 ± 9.28 (−14.63 to 35.90)	NA	NA
Koerner et al, 2013[27]	328	Mixed	American	CT	NA	8.84 ± 9.66	M: 8.70 ± 9.44 F: 9.51 ± 10.72 $P = 0.56$	NA
Botser et al, 2012[14]	129	NA	American	CT or MRI	36 (14 to 74)	CT: 15.9 (−6 to 38.5) MRI: 7 (−19.5 to 36)	NA	NA
Bargar et al, 2010[15]	46*	NA	American	CT	61 (42 to 77)	13.8 ± 7.9 (−6.1 to 32.7)	NA	NA
Husmann et al, 1997[29]	310	White	French	CT	62 (42 to 76)	24.7 ± 8.7 (0.29 to 44.5)	NA	NA
Braten et al, 1992[28]	200	White	Norwegian	Ultrasound	M: 35 (16 to 65) F: 35 (20 to 60)	16 (−2 to 33)	M: 14 ± 7.8 (−2 to 29) F: 18 ± 7.4 (3 to 33)	Mean difference 3.8 range 0–13
Hoaglund et al, 1980[23]	143	White	British	Cadaver	NA	(−2 to 35)	M:7 (−2 to 35) (S = 112) F:10 (−2 to 25) (S = 31)	NA
Reikeras et al, 1982[16]	96	NA	Norwegian	Cadaver	NA	10.4 ± 6.7	M: 10.2 ± 6.9 (N = 24) F: 10.7 ± 6.5 (N = 24); $P > 0.05$	NA
Wright et al, 2014[17]	60 *	White	Netherlander	CT	83 ± 2.8 (80 to 90)	12.6 ± 8.2	M: 9.8 ± 7.4 (N = 30) F: 15.5 ± 8.1 (N = 30) $P < 0.05$	NA
Khang et al, 2003[30]	238	Asian	Korean	CT: 200 Cadaver: 38	NA	CT: 17.9 ± 10.7 Cadaver:17.9 ± 7.4 Total:17.9 ± 10.2 (2 to 30)	NA	NA
Maruyama et al, 2001[2]	200	Asian	Japanese	Cadaver	M: 57.9 ± 12.2 (28 to 82) F: 57.5 ± 13.5 (18 to 82)	9.8 ± 8.5(−15 to 34)	M: 9.8 ± 9.0 (−15 to 30) (N = 50) F: 9.8 ± 8.0 (−12 to 34) (N = 50) $P = 0.954$	NA
Hoaglund et al, 1980[23]	151	Asian	HK Chinese	Cadaver	NA	(−4 to 36)	M:14 (−4 to 36) (S = 116) F: 16 (7 to 28) (S = 35)	NA
Yun et al, 2013[1]	112	Asian	Korean	CT	60.9 ± 3.9 (53 to 73)	9.0 ± 8.1(6.9 to 11.1)	NA	L: 9.0 ± 7.4 (7.1 to 10.9) (S = 56) R: 9.0 ± 8.8 (6.7 to 11.3) (S = 56)
Mahaisavariya et al, 2002[21]	108	Asian	Thai	CT	48.5 (22 to 83)	11.37 ± 7.65 (0.13 to 34.92)	NA	NA
Rawal et al, 2012[20]	98	Asian	Indian	CT	61.3 (40 to 81)	10.9 ± 4.22	M: 8.49 ± 4.68 (5.5 to 20.5) (N = 31) F: 12.6 ± 2.92 (6.2 to 20) (N = 29) $P = 0.001$	NA
Sugano et al, 1998[18]	30*	Asian	Japanese	CT	56 (20 to 78)	19.8 ± 9.3 (3.0 to 50.1)	M: 16.9 ± 7.1 (N = 15) F: 22.6 ± 10.6 (N = 15) $P > 0.05$	NA
Lee et al, 2006[19]	24*	Asian	Korean	CT	69.3 ± 6.3	18.5 ± 7.2	F: 18.5 ± 7.2	NA
Umebese et al, 2005[31]	116	African	Nigerian	Radiograph	NA	28 ± 5	$P > 0.05$	NA

CT = computed tomography, F = females, L = left side, M = males, M/M ± SD = mean/mean ± standard deviation, MRI = magnetic resonance imaging, N = total number of patients, NA = not applicable, R = right side, S = total number of specimens.
*Case number.

TABLE 5. Previous Reports Regarding Outcomes of Neck-shaft Angle for all, for Genders and Body Lateralities

Study and year	Specimen or Case No.	Ethnicity	Population	Method	Age (M ± SD) (Range), Y	Value for All (M/M ± SD) (range)	Sex Difference (M/M ± SD) (Range)	Laterality Difference (M/M ± SD) (Range)
Gilligan et al, 2013[11]	8271	Mixed	Mixed	Cadaver	NA	126.4 ± 5.57 (105–148)	M: 125.21 ± 5.55 (108–144) (S = 1882) F: 125.17 ± 5.69 (105–142) (S = 1466) $P = 0.851$	L: 127.02 ± 5.36 (108–148) (S = 4141) R: 125.71 ± 5.69 (105–145) (S = 4130) $P < 0.001$
Noble et al, 1988[33]	200	NA	American	Cadaver	69.9 (22–95)	124.7 ± 7.4 (105.7–154.5)	NA	NA
Husmann et al, 1997[29]	310	White	French	Radiograph	62 (42–76)	129.2 ± 7.8 (115.2–149.6)	NA	NA
Reikeras et al, 1982[16]	96	NA	Norwegian	Cadaver	NA	127.7 ± 7.6	M: 128.3 ± 7.9 (N = 24) F: 127.0 ± 7.2 (N = 24) $P > 0.05$	NA
Hoaglund et al, 1980[23]	66	White	British	Cadaver	NA	(115–161)	M:136 (120–161) (S = 52) F:133 (115–145) (S = 11)	NA
Wright et al, 2014[17]	60*	White	Netherlander	CT	83 ± 2.8 (80–90)	124.2 ± 5.0	M:125.5 ± 5.0 (N = 30) F: 123.0 ± 4.7 (N = 30)	NA
Rubin et al, 1992[34]	32	NA	French	Radiograph	82 (70–95)	122.9 ± 7.6 (100.7–137.8)	NA	NA
Khang et al, 2003[30]	238	Asian	Korean	CT: 200 Cadaver: 38	NA	CT: 125.6 ± 6.0 Cadaver: 128.2 ± 5.5	NA	NA
Roy et al, 2014[25]	204	Asian	Eastern Indian	Radiograph	> 50	130.57 ± 3.0	M: 131.0 (N = 42) F: 130.37 (N = 60) $P = 0.21$	M: (L vs R) 130.99 ± 3.77 vs. 130.89 ± 3.61 $P = 0.9$ F: (L vs R) 130.2 ± 2.56 vs 129.93 ± 3.82 $P = 0.52$
Maruyama et al, 2001[2]	200	Asian	Japanese	Cadaver	M: 57.9 ± 12.2 (28–82) F: 57.5 ± 13.5 (18–82)	125.0 ± 4.8 (106–137)	M: 124.7 ± 5.3 (106–135) (N = 50) F: 125.3 ± 4.2 (115–137) (N = 50) $P = 0.395$	NA
Gilligan et al, 2013[11]	115	Asian	Chinese	Cadaver	NA	127.2 ± 5.0 (113–139)	NA	NA
Mahaisavariya et al, 2002[21]	108	Asian	Thai	CT	48.5 (22–83)	128.04 ± 6.14 (110.07–140.30)	NA	NA
Rawal et al, 2012[20]	98	Asian	Indian	CT	61.3 (40–81)	124.42 ± 5.49	M: 127.99 ± 5.4 (107–136) (N = 31) F: 126.8 ± 5.57 (100–130) (N = 29) $P = 0.289$	NA
Hoaglund et al, 1980[23]	51	Asian	HK Chinese	Cadaver	NA	(115–152)	M:135 (115–152) (S = 42) F: 134 (127–142) (S = 9)	NA
Sugano et al, 1998[18]	30*	Asian	Japanese	Radiograph	56 (20–78)	126 (117–142)	NA	NA

CT = computed tomography, F = females, L = left side, M = males, M/M ± SD = mean/mean ± standard deviation, MRI = magnetic resonance imaging, N = total number of patients, NA = not applicable, R = right side, S = total number of specimens.
* Case number.

TABLE 6. Previous Reports Regarding Outcomes of Acetabular Anteversion for all, for Sexes, and Body Lateralities

Study and Year	Specimen or Case No.	Ethnicity	Population	Method	Age (M ± SD) (Range), Years	Values for All (M/M ± SD) (Range)	Sex Difference (M/M ± SD) (Range)	Laterality Difference (M/M ± SD) (Range)
Stem et al, 2006[35]	200	NA	American	CT	Median age: 68 (18–88)	23 ± 5 (12–39)	M:22 ± 6 (12–39) (N = 17) (≤70 years) 22 ± 6 (13–35) (N = 25) (>70 years) F:23 ± 5 (15–35) (N = 40) (≤70 years) 25 ± 5 (17–34) (N = 18) (>70 years)	NA
Bargar et al, 2010[15]	46*	NA	American	CT	61 (42–77)	15.1 ± 6.7 (0.71–29.4)	NA	NA
Murtha et al, 2008[36]	42*	White: 40 Afro-Caribbeans: 2	American	CT	M: 54.2 (38–74) F: 56.8 (37–79)	NA	M: 19.3(8.5–32.3) (N = 20) F: 24.1(14.0–33.3) (N = 22) $P = 0.021$	NA
Rubalcava et al2012[39]	118*	NA	Mexican	CT	47.7 ± 16.7 (18–85)	18.6 ± 4.1 (10–32)	M:17.3 ± 3.5 (10–26) (N = 60) F: 19.8 ± 4.7 (10–31) (N = 58)	L: 18.0 ± 3.9 (10–30) R: 19.2 ± 4.4 (10–32) $P > 0.05$
Tallroth et al, 2006[37]	70	NA	Finnish	CT	Median age: 45(14–79)	21 ± 7 (4–37)	M: 17 ± 6 (4–30) (N = 20) F: 23 ± 7 (10–37) (N = 20) $P < 0.01$	$P > 0.05$
Zeng et al, 2012[22]	100*	Asian	Chinese	CT	M: 48.2 ± 8.47 F: 44.2 ± 5.27	(5–29)	M: (L vs R)16.0 ± 5.74 vs 17.5 ± 5.73 (5–29) F: (L vs R)17.6 ± 4.80 vs 18.1 ± 5.55 (7–29) $P = 0.058$	L: (M vs F) 16.0 ± 5.74 vs 17.6 ± 4.80 R: (M vs F) 17.5 ± 5.73 vs 18.1 ± 5.55 $P = 0.230$
Maruyama et al, 2001[2]	200	Asian	Japanese	Cadaver	M: 57.9 ± 12.2 (28–82) F: 57.5 ± 13.5 (18–82)	19.9 ± 6.6 (7–42)	M: 18.5 ± 5.8 (N = 50) F: 21.3 ± 7.1 (N = 50) $P = 0.002$	NA

CT = computed tomography, F = females, L = left side, M = males, M/M ± SD = mean/mean ± standard deviation, MRI = magnetic resonance imaging, N = total number of patients, NA = not applicable, R = right side.

*Case number.

quite lower than our 133 degree. We think that this might have been caused by different climates (Beijing vs Guangzhou) involved in the 2 studies. Just as Gilligan et al[11] indicated, the climatic trends for neck-shaft angle are negative for latitude, whereas positive for temperature. Although the result of laterality-based analysis in our study is in accordance with Roy et al[25] reporting no significant laterality difference for neck-shaft angle, we found a greater value at the left side (especially in subgroup analysis for females), which was supported by Gilligan et al.[11] It requires more future investigations whether body laterality difference existed.

The present study found that acetabular anteversion was associated with age and sex but not laterality. Specifically speaking, initially, adults younger than 60 years had a significantly lower acetabular anteversion than those older than 60 years. That is to say, acetabular anteversion may increase with age. Similar to our outcomes, Stem et al[35] found a significantly higher acetabular anteversion in people older than 70 years than those younger than 70 years in females. Although the causes for such age-related change in acetabular anteversion are still not clear, just as Stem et al[35] stated, the altered acetabular orientation may be associated with an increased risk of osteoarthritis. Second, our finding that females had a significantly higher acetabular anteversion than males is in accordance with most of the previous outcomes (Table 6).[2,15,22,35–37,39] Pincer-type FAI, associated with acetabular retroversion, is more frequently observed in females, but we found females had a greater value of acetabular anteversion than males, which supports the viewpoints[38] that pincer-type FAI in females cannot be explained by differences of acetabular anteversion alone. Third, although our multiple linear regression analysis showed that acetabular anteversion may be unrelated to laterality, laterality-based analysis showed that the right side may have a higher value of acetabular anteversion than the left side, which is in consistent with Rubalcava et al.[39] We consider that this side difference may be caused by habitually dominant use of the right lower extremity in Chinese population. As the sample size of present study is still not large enough, more studies are warranted.

In our study, the femoral retroversion rate for all was 11.30% and statistically higher in males than in females (13.52% vs 4.24%, $P < 0.001$). However, Koerner et al[27] reported that the femoral retroversion rates for white Americans, African Americans, and Hispanics in males were 21.4%, 15.1%, and 7.1%, respectively, whereas18.8%, 23.5%, and 14.3% in females. Although males had a higher rate of coxa valgus than females (4.48% vs1.66%) in the present study, no statistical difference was identified. In addition, no significant differences were found regarding femoral retroversion rate and coxa valgus rate, neither between 2 age groups nor between body literalities.

Our study has several limitations. First, the measurements of femoral version, neck-shaft angle, and acetabular anteversion we reported cannot lead to a comprehensive understanding of PFG in Chinese Han adult population because there are still many other parameters of PFG, such as femoral head off set, femoral head diameter, and acetabular abduction. Second, although we tried to reduce possible bias, through independent measurement by 3 experienced observers, bias cannot have been eliminated entirely. In addition to the measurement disparity between different observers, other factors like image quality and specific measurement method also might have caused bias. Third, although findings of the present study were based on 466 adults, sex distribution in the sample size was imbalanced so that cautious attitude should be taken toward females-related findings. Moreover, it should be noted that, in addition to age, sex, and body laterality reported in present study, PFG may be affected by other factors, such as aBMD, body height, and weight. Therefore, future PFG studies should take full consideration of all the above aspects.

In summary, our study based on a larger sample size of Chinese Han population finds the following: neck-shaft angle may decrease whereas acetabular anteversion may increase with age; females may have higher values of femoral version and acetabular anteversion than males; and the right side of body may have a higher acetabular anteversion than the left side. Additionally, based on the current data, no significant differences have been identified regarding femoral retroversion rate as well as coxa valgus rate between 2 age groups or body literalities except for a significantly higher femoral retroversion rate in males.

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