Int J Clin Exp Med 2016;9(2):4453-4459
www.ijcem.com /ISSN:1940-5901/IJCEM0017603

Original Article

A retrospective analysis of effects of age on proximal femoral geometry in 466 Chinese Han healthy adults

Yi Jiang[1,2*], Nan Jiang[1,2*], Lin Peng[2], Qing Zhang[2], Wei-Ran Hu[2], Bin Yu[1,2]

[1]*Department of Orthopedics and Traumatology, Nanfang Hospital, Southern Medical University, PR China;* [2]*Guangdong Provincial Key Laboratory of Bone and Cartilage Regenerative Medicine, Nanfang Hospital, Southern Medical University, PR China.* [*]*Equal contributors.*

Received October 10, 2015; Accepted January 27, 2016; Epub February 15, 2016; Published February 29, 2016

Abstract: As important indicators in clinical orthopaedics, proximal femoral geometry (PFG) is affected by many factors. However, current information is still limited regarding the effects of age on PFG in Chinese population. Therefore, the present study aimed to explore the influences of age on PFG on Chinese Han healthy adults. PFG of femoral version (FV), neck-shaft angle (NSA), acetabular anteversion (AA), femoral offset (FO), femoral head diameter (FHD), femoral neck diameter (FND) and femoral neck length (FNL) were measured in 466 Chinese Han healthy adults (353 males and 113 females). Included adults were divided into seven groups based on age of 18 to 29 years, 30 to 39 years, 40 to 49 years, 50 to 59 years, 60 to 69 years, 70 to 79 years and over 80 years, respectively. Analyses for all and stratified analyses by gender and laterality were performed. We found significant differences of NSA (P = 0.000) and AA (P = 0.000) among the age groups, which indicated that NSA may decrease while AA may increase with age. However, no significant differences were found regarding FV (P = 0.616), FO (P = 0.631), FHD (P = 0.807), FND (P = 0.993) or FNL (P = 0.070). Outcomes of Pearson correlation analysis showed a negative relationship between NSA and age (P = 0.000) but a positive association between AA and age (P = 0.000). In the stratified analysis by gender, statistical differences were identified in males regarding NSA (P = 0.003), AA (P = 0.000) and FNL (P = 0.043). With respect to females, significant differences were found in FV (P = 0.014), AA (P = 0.024), FND (P = 0.041) and FNL (P = 0.038). Stratified analyses by body laterality revealed similar outcomes with those for all. Our outcomes suggest a negative association between NSA and age but a positive association between AA and age in the Chinese cohort we reviewed. Additionally, gender differences may exist regarding changes of PFG with age.

Keywords: Age, proximal femoral geometry, Chinese Han population, retrospective study

Introduction

As an important indicator in clinical orthopaedics, proximal femoral geometry (PFG) presents clinical significance in both hip surgeries [e.g. total hip arthroplasty (THA)] [1-3] and prediction of hip fracture risk combined with or independent from area bone mineral density (BMD) [4-11]. The requirement of THA is to create a stable anatomical articulation with an optimum range of motion. To achieve this goal, several important factors or steps should be considered or taken. One of the most important host factors is PFG, which should be given full consideration during the surgery as inappropriate size or incorrect placement of the prosthesis may increase the risk of dislocation, aseptic loosening and femoacetabular impingement [12-14].

Additionally, PFG can be also used in prediction of fracture risk in proximal femur. Gundi et al. [8] indicated that the incidence of hip fractures was significantly higher in females with a wider femoral neck-shaft angle (NSA). Im et al. [4] reported that patients suffered from femoral intertrochanteric fractures had a significantly greater NSA value and they also found that a lower value of femoral offset (FO) resulted in elevated incidence of femoral neck fractures. As another two important parameters of PFG, femoral neck diameter (FND) and femoral neck length (FNL), independent or combined with areal BMD, accounted for postmenopausal osteoporotic fractures in females [7, 9-11]. Yang et al. [6] indicated that the fracture risk is increased with increased FNL and FND, however, there was also a different opinion, just as Yang el al. [6] found that although a positive relationship was found between a longer FNL and incidence of hip fractures, no direct association was identified between FND and hip fractures.

Moreover, PFG also participates in the etiogenesis of some hip disorders such as developmental dysplasia of the hip (DDH), gluteal tendinopathy, hip osteoarthritis and greater trochanteric pain syndrome (GTPS). Jia et al. [15] indicated that a greater value of acetabular anteversion (AA) in patients with DDH. Moulton et al. [16] reported that an increased AA may contribute to the pathogenesis of gluteal tendinopathy. Giori et al. [17] found that acetabular retroversion is associated with hip osteoarthritis. Li et al. [18] revealed that a larger femoral version (FV) may result in osteoarthritis in dysplastic hips. Fearon et al. [19] showed that a lower NSA value is a risk factor for GTPS.

PFG is affected by many factors, such as ethnicity, age, gender, body laterality, even climate and lifestyle [20]. Although a large amount of studies investigated PFG parameters, limited studies focused on the effects of age on PFG [11, 21-23]. Additionally, most of the published PFG studies were conducted in Europe, Africa, America and Asian countries such as Japan [24], Korean [25] and Indian [3], current PFG studies regarding Chinese population were still limited. Although several studies [2, 6, 14, 15, 18, 26-28] reported PFG characteristics of Chinese population, the sample size were limited and analyses were insufficient, especially regarding the effect of age on PFG. Moreover, given the predicted increase of the musculoskeletal degenerations and fractures in the aging population, it is quite necessary to quantify the variation of PFG parameters in the population of China, health care system of which may have to face a particularly increased load in the next decades. Therefore, based on the above reasons, we conducted this study to explore the effects of age on PFG in Chinese Han healthy adults. We hypothesized that PFG parameters may be affected by age.

Materials and methods

Study design, setting and data source

This retrospective study aimed to explore the influences of age on PFG. Measurement of PFG was conducted using picture archiving and communication systems (PACS). Data were collected in patients who received imaging tests of the femur and acetabulum between January 1st, 2009 and October 31st, 2014. PFG parameters for measurement included FV, NSA, AA, FO, femoral head diameter (FHD), FND and FNL.

Inclusion and exclusion criteria

Inclusion criteria of the study were patients 1) of Chinese Han adult population, 2) with eligible imaging data for measurement, 3) without disorders that might affect the accuracy of measurement. Exclusion criteria included 1) other ethnicities, 2) ineligible imaging data, 3) previous hip disorders which may have an influence on PFG parameters including hip fractures, hip arthritis and hip tumor, 4) hip deformities, 5) previous hip surgeries.

If only one body side was available and eligible for measurement, this single side was also included for measurement.

Measurement methods

The seven PFG parameters were measured independently by three experienced observers. If there were any discrepancies regarding angle of more than 5° or length of more than 5 millimeters between any of the two reviewers, measurements were performed by again. The mean values were used for statistical analysis.

We used the Weiner method [29] to measure FV, which is defined as superimposing outcomes of femoral neck axis and distal femoral condylar axis. NSA, FO and FHD were measured on standard anterior-posterior radiographs of proximal femur or pelvis [3]. NSA is defined as the intersection angle between femoral neck axis and proximal femoral shaft axis. FO is defined as perpendicular distance from the center of the femoral head to the axis of the femoral shaft. FHD is depicted as diameter of a perfect circle drawn around the femoral head. AA was generated by the angle of a line between the anterior and posterior acetabular ridge with a reference line perpendicular to a line between the posterior pelvic margins at the sciatic notch level [27]. FND was measured in its narrowest section perpendicular to the hip axis [30] and FNL is the distance between the femoral shaft axis and the center of the femoral head [10].

Table 1. Comparisons among different age groups regarding the PFG parameters for all

Age groups	18 to 29 years	30 to 39 years	40 to 49 years	50 to 59 years	60 to 69 years	70 to 79 years	Over 80 years	*P values*
FV	11.98 ± 10.09	10.45 ± 9.48	10.80 ± 9.35	9.58 ± 8.72	11.31 ± 9.54	10.42 ± 8.00	10.40 ± 9.33	0.616
NSA	134.19 ± 4.28	133.93 ± 4.17	134.75 ± 4.06	133.32 ± 4.42	132.43 ± 4.71	132.36 ± 4.33	132.48 ± 4.65	0.000
AA	15.77 ± 4.38	17.48 ± 4.02	19.04 ± 5.13	18.31 ± 5.12	19.29 ± 5.39	18.87 ± 5.44	20.19 ± 5.39	0.000
FO	35.49 ± 3.78	35.01 ± 3.48	35.87 ± 6.27	34.82 ± 4.85	35.50 ± 4.55	36.04 ± 4.81	36.02 ± 4.71	0.631
FHD	45.45 ± 3.81	45.86 ± 2.91	45.65 ± 3.13	45.08 ± 3.53	45.02 ± 3.31	45.40 ± 3.56	45.04 ± 3.56	0.807
FND	30.38 ± 3.70	30.12 ± 3.04	30.58 ± 4.55	30.23 ± 4.34	30.49 ± 3.15	30.55 ± 3.85	30.31 ± 340	0.993
FNL	45.72 ± 3.71	43.74 ± 3.19	45.38 ± 4.57	43.61 ± 4.19	43.64 ± 6.09	44.24 ± 4.19	44.47 ± 3.86	0.070

PFG: proximal femoral geometry, FV: femoral version, NSA: neck-shaft angle, AA: acetabular anteversion, FO: femoral offset, FHD: femoral head diameter, FND: femoral neck diameter, FNL: femoral neck length.

Table 2. Comparisons among different age groups sorted by genders regarding the PFG parameters

Age groups	18 to 29 years	30 to 39 years	40 to 49 years	50 to 59 years	60 to 69 years	70 to 79 years	Over 80 years	*P values*
Males								
FV	10.66 ± 10.32	7.81 ± 7.29	9.44 ± 7.67	9.09 ± 8.74	9.76 ± 8.91	9.06 ± 7.77	9.27 ± 9.44	0.786
NSA	134.30 ± 4.57	134.05 ± 4.38	134.75 ± 4.25	133.31 ± 4.39	132.54 ± 4.58	132.37 ± 4.37	132.70 ± 4.59	0.003
AA	15.45 ± 4.20	17.13 ± 4.22	18.44 ± 4.65	18.02 ± 5.15	18.99 ± 5.46	18.07 ± 5.17	19.76 ± 5.59	0.000
FO	36.06 ± 4.24	35.38 ± 3.40	35.53 ± 6.31	35.01 ± 4.93	35.14 ± 4.52	35.63 ± 3.93	36.11 ± 4.73	0.840
FHD	46.54 ± 3.83	46.81 ± 2.19	45.57 ± 3.19	45.44 ± 3.45	44.93 ± 3.43	46.17 ± 3.36	45.57 ± 3.68	0.106
FND	31.46 ± 4.03	30.66 ± 3.25	30.30 ± 4.71	30.57 ± 4.58	30.80 ± 3.05	31.33 ± 3.89	30.86 ± 3.60	0.786
FNL	46.35 ± 3.95	44.20 ± 3.24	44.98 ± 4.32	43.86 ± 4.43	43.07 ± 6.22	44.34 ± 4.08	44.39 ± 3.58	0.043
Females								
FV	15.67 ± 8.64	22.82 ± 9.01	17.29 ± 13.59	12.62 ± 8.22	17.25 ± 9.70	14.28 ± 7.40	12.43 ± 8.85	0.014
NSA	133.91 ± 3.59	133.48 ± 3.41	134.76 ± 2.79	133.17 ± 4.68	132.04 ± 5.25	132.35 ± 4.24	132.06 ± 4.78	0.425
AA	16.69 ± 4.85	18.99 ± 2.71	22.10 ± 6.49	19.91 ± 4.73	20.46 ± 5.02	21.14 ± 5.59	21.01 ± 4.93	0.024
FO	34.37 ± 2.42	33.93 ± 3.74	37.76 ± 6.10	33.77 ± 4,51	36.93 ± 4.49	37.07 ± 6.48	35.79 ± 4.75	0.140
FHD	43.35 ± 2.83	43.15 ± 3.12	46.06 ± 2.91	43.10 ± 3.45	45.38 ± 2.86	43.45 ± 3.34	43.76 ± 2.96	0.100
FND	28.28 ± 1.54	28.56 ± 1.61	32.11 ± 3.36	28.37 ± 1.91	29.22 ± 3.33	28.59 ± 2.98	29.01 ± 2.46	0.041
FNL	44.49 ± 2.93	42.40 ± 2.79	47.59 ± 5.59	42.27 ± 2.15	45.91 ± 5.03	43.97 ± 4.49	44.66 ± 4.52	0.038

PFG: proximal femoral geometry, FV: femoral version, NSA: neck-shaft angle, AA: acetabular anteversion, FO: femoral offset, FHD: femoral head diameter, FND: femoral neck diameter, FNL: femoral neck length.

Statistical analysis

Statistical analysis was performed by the SPSS 17.0 software (Chicago, Illinois, USA). Continuous data were presented as the mean and standard deviation. One-way analysis of variance test (One-Way ANOVA) method was used for continuous variables. Pearson correlation analysis was used to analyze potential relationship between age and PFG parameters. Significant difference was defined as $P \leq 0.05$.

Results

Demographics

Finally, 466 patients were included for analysis. The overall mean age for all was 62.44 years (SD, 18.72) (range, 18 to 93). The average ages were 61.39 years and 65.72 years for males and females, respectively.

Effects of age on the PFG parameters for all

As shown in **Table 1**, significant differences were identified regarding the values of NSA (P = 0.000) and AA (P = 0.000) among the age groups, which suggests that there was a tendency that NSA may decrease while AA may increase with age. However, no significant differences were found regarding FV (P = 0.616), FO (P = 0.631), FHD (P = 0.807), FND (P = 0.993) or FNL (P = 0.070) among the age groups (**Table 1**).

Effects of age on the PFG parameters by gender

In the stratified analysis by gender, statistical differences were identified in males regarding NSA (P = 0.003), AA (P = 0.000) and FNL (P = 0.043). With respect to females, significant differences were found in FV (P = 0.014), AA (P =

Table 3. Comparisons among different age groups sorted by body laterality regarding the PFG parameters

Age groups	18 to 29 years	30 to 39 years	40 to 49 years	50 to 59 years	60 to 69 years	70 to 79 years	Over 80 years	*P values*
Left side								
FV	11.82 ± 10.23	10.13 ± 6.64	10.85 ± 9.60	8.76 ± 9.23	11.90 ± 9.33	10.49 ± 8.39	11.51 ± 9.64	0.483
NSA	134.45 ± 3.87	134.30 ± 4.14	134.73 ± 4.44	133.69 ± 4.38	132.44 ± 4.81	132.50 ± 3.96	132.84 ± 4.45	0.025
AA	15.40 ± 4.49	17.46 ± 3.75	18.33 ± 5.13	17.99 ± 4.86	19.00 ± 5.64	18.76 ± 5.55	19.61 ± 5.01	0.003
FO	36.02 ± 3.78	34.87 ± 4.22	36.85 ± 4.75	35.13 ± 4.62	36.05 ± 4.46	36.40 ± 4.60	36.62 ± 5.13	0.654
FHD	45.53 ± 3.54	45.67 ± 3.03	45.67 ± 2.89	44.65 ± 3.53	44.98 ± 3.10	45.23 ± 3.42	45.07 ± 3.53	0.894
FND	29.95 ± 3.42	29.78 ± 3.22	31.04 ± 2.73	29.56 ± 5.21	30.43 ± 2.93	29.98 ± 3.79	30.14 ± 2.78	0.711
FNL	45.51 ± 3.68	44.43 ± 2.77	45.97 ± 4.86	43.77 ± 4.11	44.28 ± 4.43	44.62 ± 4.09	44.71 ± 4.03	0.461
Right side								
FV	12.14 ± 10.09	10.76 ± 11.72	10.74 ± 9.20	10.39 ± 8.17	10.67 ± 9.78	10.35 ± 7.63	9.29 ± 8.94	0.873
NSA	133.95 ± 4.67	133.59 ± 4.25	134.78 ± 3.71	132.96 ± 4.47	132.42 ± 4.63	132.23 ± 4.69	132.12 ± 4.85	0.041
AA	16.13 ± 4.30	17.50 ± 4.34	19.75 ± 5.08	18.62 ± 5.38	19.59 ± 5.14	18.97 ± 5.35	20.77 ± 5.72	0.000
FO	34.95 ± 3.79	35.12 ± 2.88	34.89 ± 7.46	34.50 ± 5.13	34.91 ± 4.61	35.63 ± 5.05	35.41 ± 4.23	0.957
FHD	45.38 ± 4.15	46.02 ± 2.89	45.63 ± 3.41	45.51 ± 3.53	45.07 ± 3.56	45.58 ± 3.72	45.00 ± 3.64	0.939
FND	30.80 ± 4.00	30.40 ± 2.95	30.12 ± 5.85	30.92 ± 3.14	30.54 ± 3.41	31.19 ± 3.85	30.49 ± 3.95	0.925
FNL	45.92 ± 3.81	43.17 ± 3.47	44.79 ± 4.27	43.45 ± 4.31	42.93 ± 7.47	43.81 ± 4.28	44.22 ± 3.70	0.290

PFG: proximal femoral geometry, FV: femoral version, NSA: neck-shaft angle, AA: acetabular anteversion, FO: femoral offset, FHD: femoral head diameter, FND: femoral neck diameter, FNL: femoral neck length.

Table 4. Correlation analysis between PFG parameters and age for all

PFG parameters	Correlation coefficient with age (r)	*P values*
FV	-0.031	0.354
NSA	-0.161	0.000
AA	0.192	0.000
FO	0.054	0.217
FHD	-0.043	0.332
FND	0.011	0.811
FNL	-0.060	0.171

PFG: proximal femoral geometry, FV: femoral version, NSA: neck-shaft angle, AA: acetabular anteversion, FO: femoral offset, FHD: femoral head diameter, FND: femoral neck diameter, FNL: femoral neck length.

0.024), FND (P = 0.041) and FNL (P = 0.038) (**Table 2**).

Effects of age on the PFG parameters by body laterality

Outcomes of the stratified analysis by body laterality showed that statistical differences were found of NSA and AA among the age groups in both sides. However, insignificant differences were identified regarding FV, FO, FHD, FND or FNL among the age groups (**Table 3**).

Pearson correlation analysis

In the correlation analysis for all, statistical differences were identified between NSA and age (r = -0.161, P = 0.000) as well as AA and age (r = 0.192, P = 0.000), which indicated that NSA may have a negative correlation while AA may have a positive correlation with age, respectively. However, no significant correlations were found between age and another PFG parameters including FV (P = 0.354), FO (P = 0.217), FHD (P = 0.332), FND (P = 0.811) or FNL (P = 0.171) (**Table 4**).

Discussion

With the improvement of living standards and the medical technology, people become more and more longevity, resulting in the increasing number of elderly people. Improved knowledge regarding the effects of age on PFG will help surgeon better reconstruct PFG during hip surgeries, especially for the aged. Our data may be used as a reference to design more suitable implants for the aged in Chinese population. Furthermore, the assessment for the effects of age on PFG may partly account for the higher incidence of hip fractures in older people.

In this Chinese cohort we reviewed, NSA may decrease while AA may increase with age, which was supported by the outcomes of correlation analysis. Additionally, gender differences may exist regarding PFG changes with age. In the stratified analysis by gender, statistical differences were identified in males regarding NSA, AA and FNL. While in females, significant differences were found in FND, FNL, FV and AA.

Outcomes of the stratified analysis by body laterality showed that statistical differences were found of NSA and AA among the age groups in both sides, which were in accordance with the outcomes for all.

The present study showed that NSA may decrease with age, which is in agreement with a recent study conducted by Wang el al. [26], who investigated growth and aging of proximal femoral bone in females spanning three generations. They found that grandmothers had the narrowest NSA. We considered that this change of NSA may be associated with areal BMD. It is known that areal BMD decreases with age, which may result in gradually decreased support strength from the proximal femur and as a consequence of decreased value of NSA. In addition to the above significant finding, we also found that AA may increase with age, which was supported by Stem et al. [31] based on a retrospective analysis of 100 pelvic CT scans. Although the cause of the age-related changes in AA is not clear, we considered it may be associated with hip and spinal disorders (e.g. hip osteoarthritis and kyphosis), the incidences of which may increase in senior citizens. As for the consequences of increased value of AA, Stem et al. [31] indicated that the altered acetabular orientation may result in an increased risk of hip osteoarthritis. Outcomes of the correlation analysis confirmed the above changes of NSA and AA with age, which showed a positive association between NSA and age while a negative association between AA and age.

In the stratified analysis by gender, in addition to the significant changes of NSA and AA in males, statistical difference of FNL was also found among the age groups, which revealed a slightly decreased tendency of FNL from 18 to 70 years. We attributed the changes of FNL with age mainly to the lifestyle [20] in Chinese population. It is known that physical labor with heavy work load accounts for a large percentage of all working styles in China and the accumulation of work load with age may affect the PFG like FNL. With respect to females, significant differences were identified regarding FV AA, FND and FNL. An interesting phenomenon was found that PFG parameters apart from FV in females achieved peak values in 40 to 49 age groups, regardless of significant or insignificant changes of the parameters with age. This finding may be interpreted as the influence of hormone changes. As for the peak value of FV, it was at the age stage of 30 to 39 years. We are still unclear the reason accounting for this variance. However, considering the limited sample size for subgroup analyses (especially in females), cautious attitude should be taken and future more studies with a larger sample size are warranted. In consistent with tendency of PFG changes with age for all, results of the stratified analysis by body laterality showed that NSA may decrease while AA may increase with age in both sides.

The present study had several limitations. Initially, although seven types of PFG parameters were measured, it is still insufficient for comprehensive recognition of the PFG characteristics in Chinese healthy adults. Other PFG parameters such as hip axis length, femoral neck axis length and intertrochanter-head center distance [9] should also be noted. Additionally, as mentioned above, the sample size of the current study was still limited, which may affect the outcomes. Therefore, cautious attitude should be taken, especially for outcomes originated from females. Moreover, our study only focused on the effects of age on PFG and it should be noted that other factors including ethnicity, gender, BMD may also affect PFG. In-depth studies should focus on other potential factors and investigate the interactions of these factors.

In summary, outcomes of the present study showed a negative association between NSA with age while a positive association between AA and age in this group of Chinese healthy adults we analyzed. In addition, gender difference may exist with regard to the PFG changes with age. However, considering the limited sample as well as gender imbalance of the present study, larger sample sizes with gender matched studies are necessary to achieve a more accuracy conclusion.

Acknowledgements

The authors are grateful for the support of Natural Science Foundation of China (Grant No. 31440043).

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Bin Yu, Department of Orthopedics and Traumatology, Nanfang Hospital, Southern Medical University, PR China; Guangdong Provincial Key Laboratory of Bone and Cartilage Regenerative Medicine, Nanfang Hospital, Southern Medical University, PR China. Tel: +86-20-6164-1741; Fax: +86-20-6136-0066; E-mail: nanfang-hot@126.com

References

[1] Wassilew GI, Janz V, Heller MO, Konig C, Perka C, Sudhoff I, Seeger JB and Hasart O. Ultrasound-based computer navigation: an accurate measurement tool for determining combined anteversion? Technol Health Care 2012; 20: 535-543.

[2] Yang Z, Jian W, Li ZH, Jun X, Liang Z, Ge Y and Shi ZJ. The geometry of the bone structure associated with total hip arthroplasty. PLoS One 2014; 9: e91058.

[3] Roy S, Kundu R, Medda S, Gupta A and Nanrah BK. Evaluation of proximal femoral geometry in plain anterior-posterior radiograph in eastern-Indian population. J Clin Diagn Res 2014; 8: Ac01-03.

[4] Im GI and Lim MJ. Proximal hip geometry and hip fracture risk assessment in a Korean population. Osteoporos Int 2011; 22: 803-807.

[5] Patron MS, Duthie RA and Sutherland AG. Proximal femoral geometry and hip fractures. Acta Orthop Belg 2006; 72: 51-54.

[6] Yang RS, Wang SS and Liu TK. Proximal femoral dimension in elderly Chinese women with hip fractures in Taiwan. Osteoporos Int 1999; 10: 109-113.

[7] Dincel VE, Sengelen M, Sepici V, Cavusoglu T and Sepici B. The association of proximal femur geometry with hip fracture risk. Clin Anat 2008; 21: 575-580.

[8] Gnudi S, Sitta E and Pignotti E. Prediction of incident hip fracture by femoral neck bone mineral density and neck-shaft angle: a 5-year longitudinal study in post-menopausal females. Br J Radiol 2012; 85: e467-473.

[9] Bergot C, Bousson V, Meunier A, Laval-Jeantet M and Laredo JD. Hip fracture risk and proximal femur geometry from DXA scans. Osteoporos Int 2002; 13: 542-550.

[10] Nakamura T, Turner CH, Yoshikawa T, Slemenda CW, Peacock M, Burr DB, Mizuno Y, Orimo H, Ouchi Y and Johnston CC Jr. Do variations in hip geometry explain differences in hip fracture risk between Japanese and white Americans? J Bone Miner Res 1994; 9: 1071-1076.

[11] Faulkner KG, Cummings SR, Black D, Palermo L, Gluer CC and Genant HK. Simple measurement of femoral geometry predicts hip fracture: the study of osteoporotic fractures. J Bone Miner Res 1993; 8: 1211-1217.

[12] Kay RM, Jaki KA and Skaggs DL. The effect of femoral rotation on the projected femoral neck-shaft angle. J Pediatr Orthop 2000; 20: 736-739.

[13] McGrory BJ, Morrey BF, Cahalan TD, An KN and Cabanela ME. Effect of femoral offset on range of motion and abductor muscle strength after total hip arthroplasty. J Bone Joint Surg Br 1995; 77: 865-869.

[14] Lu M, Zhou YX, Du H, Zhang J and Liu J. Reliability and validity of measuring acetabular component orientation by plain anteroposterior radiographs. Clin Orthop Relat Res 2013; 471: 2987-2994.

[15] Jia J, Li L, Zhang L, Zhao Q and Liu X. Three dimensional-CT evaluation of femoral neck anteversion, acetabular anteversion and combined anteversion in unilateral DDH in an early walking age group. Int Orthop 2012; 36: 119-124.

[16] Moulton KM, Aly AR, Rajasekaran S, Shepel M and Obaid H. Acetabular anteversion is associated with gluteal tendinopathy at MRI. Skeletal Radiol 2015; 44: 47-54.

[17] Giori NJ and Trousdale RT. Acetabular retroversion is associated with osteoarthritis of the hip. Clin Orthop Relat Res 2003; 263-269.

[18] Li H, Wang Y, Oni JK, Qu X, Li T, Zeng Y, Liu F and Zhu Z. The role of femoral neck anteversion in the development of osteoarthritis in dysplastic hips. Bone Joint J 2014; 96-b: 1586-1593.

[19] Fearon A, Stephens S, Cook J, Smith P, Neeman T, Cormick W and Scarvell J. The relationship of femoral neck shaft angle and adiposity to greater trochanteric pain syndrome in women. A case control morphology and anthropometric study. Br J Sports Med 2012; 46: 888-892.

[20] Gilligan I, Chandraphak S and Mahakkanukrauh P. Femoral neck-shaft angle in humans: variation relating to climate, clothing, lifestyle, sex, age and side. J Anat 2013; 223: 133-151.

[21] Beck TJ, Ruff CB, Scott WW Jr, Plato CC, Tobin JD and Quan CA. Sex differences in geometry of the femoral neck with aging: a structural analysis of bone mineral data. Calcif Tissue Int 1992; 50: 24-29.

[22] Travison TG, Beck TJ, Esche GR, Araujo AB and McKinlay JB. Age trends in proximal femur geometry in men: variation by race and ethnicity. Osteoporos Int 2008; 19: 277-287.

[23] Elbuken F, Baykara M and Ozturk C. Standardisation of the neck-shaft angle and measurement of age-, gender- and BMI-related changes in the femoral neck using DXA. Singapore Med J 2012; 53: 587-590.

[24] Sugano N, Noble PC and Kamaric E. A comparison of alternative methods of measuring femoral anteversion. J Comput Assist Tomogr 1998; 22: 610-614.

[25] Yun HH, Yoon JR, Yang JH, Song SY, Park SB and Lee JW. A validation study for estimation of femoral anteversion using the posterior lesser trochanter line: an analysis of computed tomography measurement. J Arthroplasty 2013; 28: 1776-1780.
[26] Wang Q, Chen D, Cheng SM, Nicholson P, Alen M and Cheng S. Growth and aging of proximal femoral bone: a study with women spanning three generations. J Bone Miner Res 2015; 30: 424-430.
[27] Zeng Y, Wang Y, Zhu Z, Tang T, Dai K and Qiu S. Differences in acetabular morphology related to side and sex in a Chinese population. J Anat 2012; 220: 256-262.
[28] Li LY, Zhang LJ, Zhao Q and Wang EB. Measurement of acetabular anteversion in developmental dysplasia of the hip in children by two- and three-dimensional computed tomography. J Int Med Res 2009; 37: 567-575.
[29] Weiner DS, Cook AJ, Hoyt WA Jr and Oravec CE. Computed tomography in the measurement of femoral anteversion. Orthopedics 1978; 1: 299-306.
[30] Gnudi S, Ripamonti C, Lisi L, Fini M, Giardino R and Giavaresi G. Proximal femur geometry to detect and distinguish femoral neck fractures from trochanteric fractures in postmenopausal women. Osteoporos Int 2002; 13: 69-73.
[31] Stem ES, O'Connor MI, Kransdorf MJ and Crook J. Computed tomography analysis of acetabular anteversion and abduction. Skeletal Radiol 2006; 35: 385-389.