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

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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 et al. [6] found that although a positive
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A 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].
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.

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 $P \leq 0.05$.

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

<table>
<thead>
<tr>
<th>Age groups</th>
<th>18 to 29 years</th>
<th>30 to 39 years</th>
<th>40 to 49 years</th>
<th>50 to 59 years</th>
<th>60 to 69 years</th>
<th>70 to 79 years</th>
<th>Over 80 years</th>
<th>$P$ values</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSA</td>
<td>134.19 ± 4.28</td>
<td>133.82 ± 3.77</td>
<td>124.75 ± 3.06</td>
<td>123.32 ± 4.22</td>
<td>123.67 ± 3.46</td>
<td>123.67 ± 3.46</td>
<td>123.67 ± 3.46</td>
<td>0.000</td>
</tr>
<tr>
<td>AA</td>
<td>15.77 ± 4.38</td>
<td>17.48 ± 4.02</td>
<td>19.04 ± 5.13</td>
<td>18.31 ± 5.12</td>
<td>19.29 ± 5.39</td>
<td>18.87 ± 5.44</td>
<td>19.21 ± 5.49</td>
<td>0.000</td>
</tr>
<tr>
<td>FO</td>
<td>35.49 ± 3.78</td>
<td>35.01 ± 3.48</td>
<td>35.67 ± 4.27</td>
<td>34.82 ± 4.85</td>
<td>35.90 ± 4.65</td>
<td>36.64 ± 4.81</td>
<td>36.02 ± 4.71</td>
<td>0.631</td>
</tr>
<tr>
<td>FHD</td>
<td>45.45 ± 3.81</td>
<td>45.86 ± 2.91</td>
<td>46.65 ± 3.13</td>
<td>45.08 ± 3.53</td>
<td>45.02 ± 3.31</td>
<td>45.40 ± 3.56</td>
<td>45.04 ± 3.56</td>
<td>0.807</td>
</tr>
<tr>
<td>FND</td>
<td>30.38 ± 3.70</td>
<td>30.12 ± 3.04</td>
<td>30.57 ± 4.55</td>
<td>30.23 ± 4.34</td>
<td>30.40 ± 3.15</td>
<td>30.55 ± 3.85</td>
<td>30.31 ± 3.40</td>
<td>0.993</td>
</tr>
<tr>
<td>FNL</td>
<td>45.72 ± 3.71</td>
<td>43.74 ± 3.19</td>
<td>45.38 ± 4.57</td>
<td>43.61 ± 4.19</td>
<td>43.64 ± 4.09</td>
<td>44.24 ± 4.19</td>
<td>44.47 ± 3.86</td>
<td>0.070</td>
</tr>
</tbody>
</table>

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 ($P = 0.003$), AA ($P = 0.000$) and FNL ($P = 0.043$).
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Table 3. Comparisons among different age groups sorted by body laterality regarding the PFG parameters

<table>
<thead>
<tr>
<th>Age groups</th>
<th>18 to 29 years</th>
<th>30 to 39 years</th>
<th>40 to 49 years</th>
<th>50 to 59 years</th>
<th>60 to 69 years</th>
<th>70 to 79 years</th>
<th>Over 80 years</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left side</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FV</td>
<td>11.82 ± 10.23</td>
<td>10.13 ± 6.64</td>
<td>10.85 ± 9.60</td>
<td>8.76 ± 9.23</td>
<td>11.90 ± 9.33</td>
<td>10.49 ± 8.39</td>
<td>11.51 ± 9.64</td>
<td>0.483</td>
</tr>
<tr>
<td>NSA</td>
<td>134.45 ± 3.87</td>
<td>134.30 ± 4.14</td>
<td>134.73 ± 4.44</td>
<td>133.69 ± 4.38</td>
<td>132.44 ± 4.81</td>
<td>132.50 ± 3.96</td>
<td>132.84 ± 4.45</td>
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</tr>
<tr>
<td>AA</td>
<td>15.40 ± 4.49</td>
<td>17.46 ± 3.75</td>
<td>18.33 ± 5.13</td>
<td>17.99 ± 4.86</td>
<td>19.00 ± 5.64</td>
<td>18.76 ± 5.55</td>
<td>19.61 ± 5.01</td>
<td>0.003</td>
</tr>
<tr>
<td>FO</td>
<td>36.02 ± 3.78</td>
<td>34.87 ± 4.22</td>
<td>36.85 ± 4.75</td>
<td>35.13 ± 4.62</td>
<td>36.05 ± 4.46</td>
<td>36.40 ± 4.60</td>
<td>36.62 ± 5.13</td>
<td>0.654</td>
</tr>
<tr>
<td>FHD</td>
<td>45.53 ± 3.54</td>
<td>45.67 ± 3.03</td>
<td>45.67 ± 2.89</td>
<td>44.65 ± 3.53</td>
<td>44.98 ± 3.10</td>
<td>45.23 ± 3.42</td>
<td>45.07 ± 3.53</td>
<td>0.894</td>
</tr>
<tr>
<td>FND</td>
<td>29.95 ± 3.42</td>
<td>29.78 ± 3.22</td>
<td>31.04 ± 2.73</td>
<td>29.56 ± 5.21</td>
<td>30.43 ± 2.93</td>
<td>29.98 ± 3.79</td>
<td>30.14 ± 2.78</td>
<td>0.711</td>
</tr>
<tr>
<td>FNL</td>
<td>45.51 ± 3.68</td>
<td>44.43 ± 2.77</td>
<td>45.97 ± 4.86</td>
<td>43.77 ± 4.11</td>
<td>44.28 ± 4.43</td>
<td>44.62 ± 4.09</td>
<td>44.71 ± 4.03</td>
<td>0.461</td>
</tr>
<tr>
<td>Right side</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSA</td>
<td>133.95 ± 4.67</td>
<td>133.59 ± 4.25</td>
<td>134.78 ± 3.71</td>
<td>132.96 ± 4.47</td>
<td>132.42 ± 4.63</td>
<td>132.23 ± 4.69</td>
<td>132.12 ± 4.85</td>
<td>0.041</td>
</tr>
<tr>
<td>AA</td>
<td>16.13 ± 4.30</td>
<td>17.50 ± 4.34</td>
<td>19.75 ± 5.08</td>
<td>18.62 ± 5.38</td>
<td>19.59 ± 5.14</td>
<td>18.97 ± 5.35</td>
<td>20.77 ± 5.72</td>
<td>0.000</td>
</tr>
<tr>
<td>FO</td>
<td>34.95 ± 3.79</td>
<td>35.12 ± 2.88</td>
<td>34.89 ± 7.46</td>
<td>34.50 ± 5.13</td>
<td>34.91 ± 4.61</td>
<td>35.63 ± 5.05</td>
<td>35.41 ± 4.23</td>
<td>0.957</td>
</tr>
<tr>
<td>FHD</td>
<td>45.38 ± 4.15</td>
<td>46.02 ± 2.89</td>
<td>45.63 ± 3.41</td>
<td>45.51 ± 3.53</td>
<td>45.07 ± 3.56</td>
<td>45.58 ± 3.72</td>
<td>45.00 ± 3.64</td>
<td>0.939</td>
</tr>
<tr>
<td>FND</td>
<td>30.80 ± 4.00</td>
<td>30.40 ± 2.95</td>
<td>30.12 ± 5.85</td>
<td>30.92 ± 3.14</td>
<td>30.54 ± 3.41</td>
<td>31.19 ± 3.85</td>
<td>30.49 ± 3.95</td>
<td>0.925</td>
</tr>
<tr>
<td>FNL</td>
<td>45.92 ± 3.81</td>
<td>43.17 ± 3.47</td>
<td>44.79 ± 4.27</td>
<td>43.45 ± 4.31</td>
<td>42.93 ± 4.74</td>
<td>43.81 ± 4.28</td>
<td>44.22 ± 3.70</td>
<td>0.290</td>
</tr>
</tbody>
</table>


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 surgeons 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 et 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 FPG 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

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Disclosure of conflict of interest

None.
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