Anteroposterior Thickening of the Femoral Neck With Aging Decreases the "Offset" in Men

Jacob K. Johnson, Jordan B. Renner and Laurence E. Dahners

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Anteroposterior Thickening of the Femoral Neck With Aging Decreases the "Offset" in Men

Jacob K. Johnson,*† BS, Jordan B. Renner,‡ MD, and Laurence E. Dahners,§ MD
Investigation performed at the School of Medicine, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina

Background: The contour of the femoral head-neck junction has been shown to have an effect on femoroacetabular impingement (FAI), which can lead to early osteoarthritis of the hip. This study uses computed tomography (CT) to investigate changes in the femoral head, femoral neck, and joint space with aging.

Hypothesis: The ratio of the diameter of the femoral head to the diameter of the femoral neck would decrease with increasing age, thus diminishing the "offset" of the femoral neck and being a possible mechanism for cam-type FAI and resultant osteoarthritis.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: There were 20 male and 20 female patients from each decade, aged 20 to 80 years, who received pelvic and abdominal CT scans. In the axial plane, the femoral head and neck were measured from anterior to posterior, and the joint space was measured anteromedially. The ratio of the diameter of the femoral head to the diameter of the femoral neck was calculated, and patients with radiographic signs of osteoarthritis were noted. Regression analysis was performed to examine the significance of the relationships between these variables, age, and osteoarthritis.

Results: Male and female patients showed significant increases in femoral head diameter and femoral neck diameter as well as decreases in joint space width with increasing age. Male patients showed a decrease in the femoral head-neck ratio (relative neck thickening) of 0.0053 per year ($P < .0001$) or an average 18% decrease from age 20 to 80 years, while female patients did not show a significant relationship ($P = .29$). Male patients with signs of osteoarthritis had a smaller femoral head-neck ratio ($P < .0001$) than those without, while female patients did not ($P = .25$). Male and female patients with signs of osteoarthritis had a larger femoral head and femoral neck and a more narrow joint space width than those without.

Conclusion: Our results suggest that, as men age, they develop a relatively thicker femoral neck that could result in increasing cam impingement, which contributes to the known higher prevalence of osteoarthritis in men. This does not seem to be the case in women, as their femoral neck does not appear to grow as quickly.

Keywords: femoroacetabular impingement; cam; hip

The contour of the femoral head-neck junction has been associated with various pathological processes including femoroacetabular impingement (FAI), fractures of the femoral neck, and the development of early osteoarthritis of the hip.[2,4,6] In FAI, the hip "impinges" either because of an acetabulum that is excessive ("pincer" FAI) or an abnormal femur ("cam" FAI).[14] Hack et al[8] found a 14% prevalence of cam-type femoral head-neck junctions in asymptomatic patients, and Ito et al[9] found that variations in anatomy with the cam effect varied with age and sex. A decreased ratio of the diameter of the femoral head to the diameter of the femoral neck as well as a greater femoral neck width have also been associated with an increased risk of hip osteoarthritis.[6,12]

Cam FAI has been suggested to contribute to articular damage, as the abnormal contour of the femoral head-neck junction causes abnormal contact pressures within the hip that result in excessive shear stresses on the cartilage.[2] Beall et al[1] suggested criteria for findings on computed tomography (CT) that may be indicative of FAI, which include the presence of acetabular osteophytes, a decreased ratio of the diameter of the femoral head to the diameter of the femoral neck, an α angle greater than 50°, and the presence of subchondral cysts or bone

*Address correspondence to Jacob K. Johnson, BS, University of North Carolina at Chapel Hill, School of Medicine, 175 Summerwalk Circle, Chapel Hill, NC 27517 (e-mail: jacob_johnson@med.unc.edu).

†School of Medicine, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina.

‡Department of Radiology, School of Medicine, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina.

§Department of Orthopaedics, School of Medicine, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina.

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sclerosis. However, it is not clear whether patients with these problematic morphological characteristics have always had them or whether they develop to become this way.

To investigate this, we performed a cross-sectional population study to observe for changes in the absolute and relative dimensions of the femoral head and neck during aging. Our first hypothesis was that the ratio of the diameter of the femoral head to the diameter of the femoral neck would decrease over time because of periosteal bone apposition on the femoral neck. We did not expect enlargement in the femoral head because it is covered with cartilage. Thickening of the neck without enlargement of the head would diminish the "offset" of the neck and be a possible mechanism for the gradual onset of cam FAI and resultant osteoarthritis. Our second hypothesis assumed that a lower femoral head-neck ratio would be associated with signs of radiographic osteoarthritis on CT. We also elected to measure the width of the anteromedial joint space to determine if there was a significant association between joint space width in this region and signs of osteoarthritis and whether the joint space width decreased over time.

MATERIALS AND METHODS

This study was approved by the ethics committee of the University of North Carolina at Chapel Hill. We included patients aged 20 to 79 years old. Exclusion criteria included the presence of either pelvic or femoral hardware or noticeable abnormalities in the anatomy of the pelvis or proximal femur.

Patients

The researchers used the University of North Carolina picture archiving and communication system (PACS, Agfa Healthcare, Mortsel, Belgium) to find patients who had undergone routine abdominal/pelvic CT scans for nonorthopaedic or trauma-unrelated reasons at the University of North Carolina Health Care System between January 1, 2000 and December 31, 2010. The researchers collected 240 participants for the study by randomly selecting 20 male and 20 female patients in each 10-year age group from 20 to 79 years (ie, 20 male and 20 female patients who were 20-29 years, 20 male and 20 female patients who were 30-39 years, etc). The racial distribution for male patients was 60% white, 29.2% African American, 5% Hispanic, 1.7% Asian, 1.7% Native American, and 2.5% other. The racial distribution for female patients was 57.5% white, 33.3% African American, 5.8% Hispanic, 1.7% Asian, and 1.7% other.

The PACS (Agfa Healthcare) was used to digitally retrieve the CT scans and make measurements. All of the distances were measured using the calipers provided by the Agfa Impax v6.3.1.7001 software (Agfa Healthcare). The software enables straight-line measurements with an accuracy of 0.01 mm. The observer was blinded to the age of the patients at the time of measurement. Figure 1 diagrams the measurements made for each patient. These

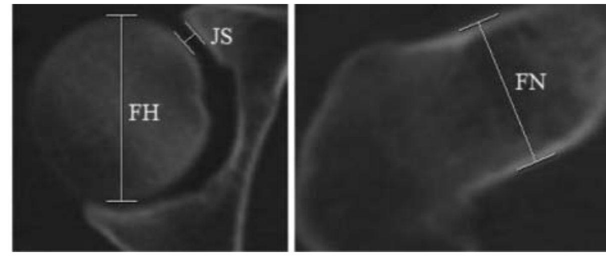

Figure 1. Measurements made for each patient included the diameter of the femoral head (FH), the width of the joint space (JS), and the diameter of the femoral neck (FN).

distances were all measured in the axial plane and include the diameter of the femoral head from anterior to posterior, where its diameter was largest, and the anteromedial joint space in the same slice, where the joint space was thinnest. The diameter across the width of the femoral neck was defined as being measured in the slice where the femoral neck was narrowest from anterior to posterior, below the base of the femoral head but not at the head-neck junction. The ratio of the diameter of the femoral head to the femoral neck was calculated. The diameter of the acetabulum was calculated by adding the femoral head diameter to 2 times the joint space. With each patient, it was also noted whether there were radiographic signs of osteoarthritis including subchondral cysts, acetabular osteophytes, and femoral head osteophytes.

Statistical Analysis

Data analysis for this project was performed using linear regression. Each measurement outcome was separated by sex and plotted against patient age. The patients were also separated by the presence or absence of radiographic signs of osteoarthritis as described previously. Linear regression lines were fit to each gender group, allowing quantitative estimation of the change in measurement over time. *P* values were then calculated for regression data, giving an estimate of the statistical significance of the relationship seen. *P* values were also calculated for each variable using the Student *t* test to determine whether a statistically significant difference was present between patients with radiographic signs of osteoarthritis and those without.

RESULTS

Our results are displayed in Table 1 as well as graphically in Figures 2 to 6. Male patients with signs of osteoarthritis had a smaller ratio of the diameter of the femoral head to the diameter of the femoral neck (relatively thicker femoral neck) ($P < .0001$), but female patients did not ($P = .25$). As expected, patients with signs of osteoarthritis had a smaller joint space width than those without signs of osteoarthritis. The diameter of the acetabulum was not found to be significantly different in those with osteoarthritis and in those without.

TABLE 1
Comparison of Variables Between Patients With Signs of Osteoarthritis and Those Without[a]

	Male Patients			Female Patients		
	With Signs of Osteoarthritis (n = 59)	Without Signs of Osteoarthritis (n = 61)	*P* Value	With Signs of Osteoarthritis (n = 33)	Without Signs of Osteoarthritis (n = 87)	*P* Value
Femoral head diameter, cm	4.86 ± 0.23	4.75 ± 0.23	.016	4.37 ± 0.22	4.24 ± 0.21	.0045
Femoral neck diameter, cm	3.11 ± 0.22	2.89 ± 0.29	<.0001	2.59 ± 0.17	2.48 ± 0.20	.0059
Femoral head-neck ratio	1.56 ± 0.10	1.66 ± 0.14	<.0001	1.69 ± 0.10	1.72 ± 0.11	.25
Joint space width, mm	2.0 ± 0.5	2.4 ± 0.6	.001	1.8 ± 0.6	2.2 ± 0.5	.0002
Acetabulum diameter, cm	5.27 ± 0.26	5.23 ± 0.26	.51	4.73 ± 0.24	4.69 ± 0.26	.42

[a]Values are expressed as mean ± standard deviation unless otherwise indicated.

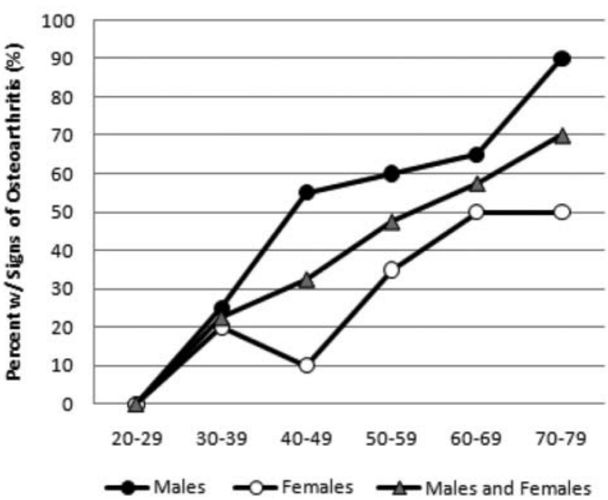

Figure 2. Percentage of patients with signs of osteoarthritis by decade.

The prevalence of radiographic signs of osteoarthritis in our patient population was 38% (92/240), with the prevalence in male patients being 49% (59/120) and in female patients being 28% (33/120). The prevalence of radiographic signs of osteoarthritis by decade in each sex as well as overall is shown in Figure 2.

Figure 3 shows that, in male patients, the ratio of the diameter of the femoral head to the diameter of the femoral neck was significantly associated with age. The ratio was found to decrease (relative femoral neck thickening) 0.0053 per year ($P < .0001$) or a total of 0.32 from age 20 to 80 years. This amounts to an average decrease of 18% in the ratio between age 20 and 80 years. However, in female patients, the ratio was not significantly associated with age ($P = .25$).

Figure 4 shows that, in male patients, the diameter of the femoral head increased 0.026 mm per year ($P = .04$) or a total of 1.56 mm from age 20 to 80 years. In female patients, the diameter of the femoral head increased at a rate of 0.024 mm per year ($P = .0406$) or a total of 1.44 mm from age 20 to 80 years.

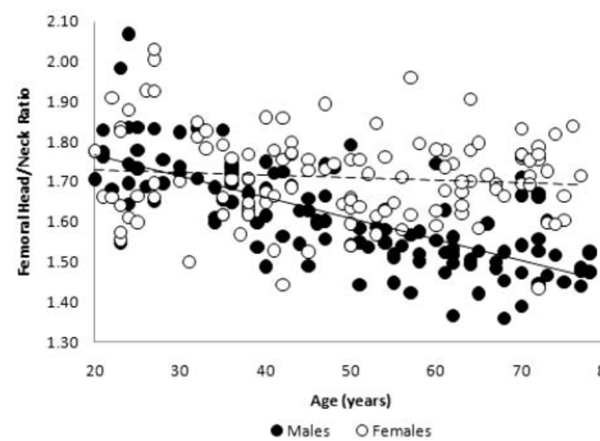

Figure 3. Ratio of the diameter of the femoral head to the diameter of the femoral neck versus age.

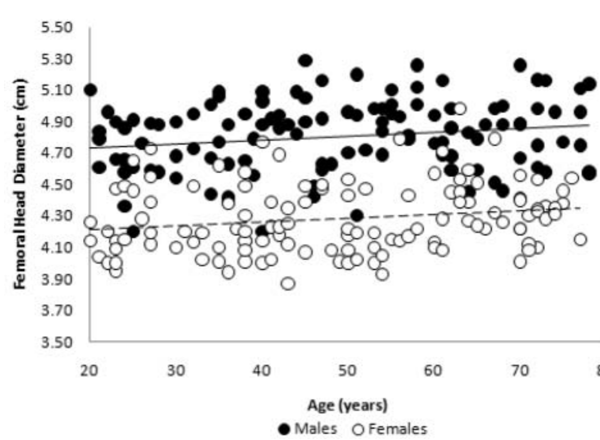

Figure 4. Diameter of the femoral head versus age.

Figure 5 shows that the diameter of the femoral neck also increased in both sexes. In male patients, the diameter increased 0.112 mm per year ($P < .0001$) or a total of 6.72 mm from age 20 to 80 years. In female patients, the diameter increased at a lower rate of 0.022 mm per year ($P = .0398$) or a total of 1.32 mm from age 20 to 80 years.

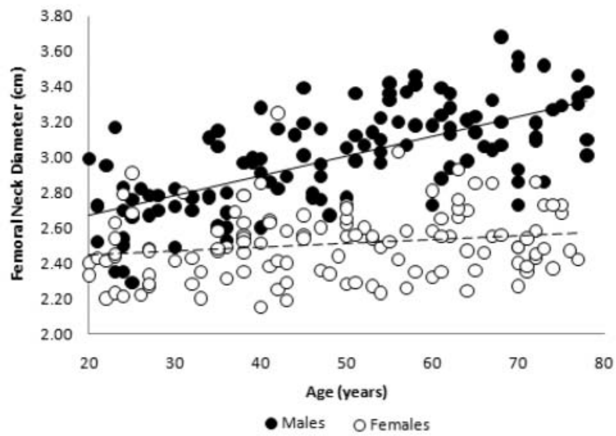

Figure 5. Diameter of the femoral neck versus age.

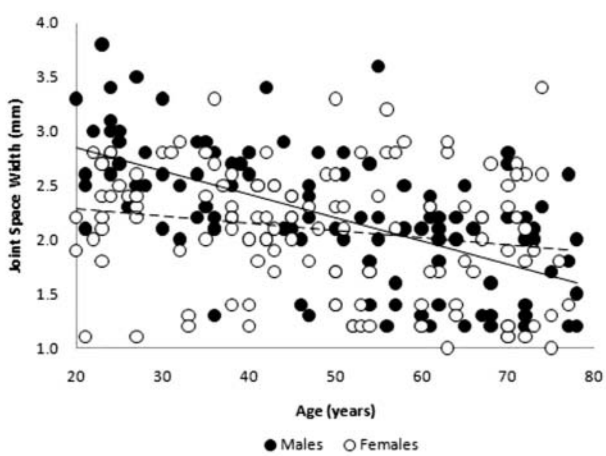

Figure 6. Width of the joint space versus age.

Figure 6 shows that the width of the joint space decreased with age in both male and female patients. In male patients, the joint space width decreased 0.022 mm per year ($P < .0001$) or a total of 1.32 mm from age 20 to 80 years. In female patients, the decrease was smaller at 0.0065 mm per year ($P = .0405$) or a total of 0.39 mm from age 20 to 80 years.

DISCUSSION

These results support the hypothesis that the ratio of the diameter of the femoral head to the diameter of the femoral neck decreases (the femoral neck becomes relatively thicker and therefore has less "offset") with aging, but only significantly in men. Unexpectedly, the femoral head does increase in diameter with aging, but the femoral head-neck ratio was shown to decrease 18% over 60 years in male patients, meaning that the femoral neck is enlarging at a significantly faster rate than the femoral head in men. This ratio was significantly different between male patients with radiographic signs of osteoarthritis (as described previously) and those without, but this was not the case in women. It has been demonstrated that a wider femoral neck as well as the formation of femoral osteophytes and the displacement of the head posteriorly in slipped capital femoral epiphysis increase the α angle, which is a measure of cam impingement severity.[16] Therefore, it is likely that the patients with a low femoral head-neck ratio were more likely to suffer from cam hip impingement that was associated with their development of signs of osteoarthritis and joint space narrowing.

Female patients did not have statistically significant associations between the ratio of the diameter of the femoral head to the diameter of the femoral neck, either over time or for those who showed radiographic signs of osteoarthritis. This is perhaps not surprising, as both cam abnormalities and osteoarthritis of the hip are less common in women.[11,13]

Given its lack of periosteum, it is surprising to see that the femoral head also seemed to grow in diameter over time in both sexes, although this was also observed in a previous study where it was suggested to be caused by calcification of the deep layers of cartilage.[3] Because the femoral head appeared to become larger over time, one would expect the diameter of the acetabulum to grow larger as well to fit around it, but this was not the case. The diameter of the acetabulum as calculated showed no statistically significant enlargement over time or correlation between those with signs of osteoarthritis and those without for either sex. Thus, the enlargement of the femoral head correlated with the amount of joint space narrowing, leaving the acetabular diameter unchanged.

The fact that the femoral neck does have periosteum would suggest that it should be able to grow at a faster rate over time than the femoral head. Both male and female patients showed a statistically significant femoral neck growth over time, but male patients had a higher rate of growth than female patients in the plane that we measured. Growth is not surprising, given that the total cross-sectional area of bone in the femoral neck has been shown to increase as much as 15% over time in a previous study, but no difference was noted between sexes.[17] While it is possible that remodeling in response to osteoporosis could contribute to an enlarging femoral neck, this was not seen as likely because enlargement was throughout life. If enlargement was caused by osteoporosis, one would expect to see more enlargement of the femoral neck in women than in men and for the rate of enlargement to increase beginning around age 50 years in women with the onset of menopause.

Previous studies have focused on the relationship of femoral neck anatomy to fractures. Some studies show no significant difference in femoral neck width between those with femoral neck fractures and those without or between those with trochanteric fractures and those without.[5,10,15] However, one study did find an association with femoral neck fractures and a larger femoral head and neck in women.[4]

Joint space width was also found to decrease at a significant rate over time in both sexes, but this was more pronounced in men. In contrast, Goker et al[7] found that the superior joint space width in female patients was significantly smaller and that there was no change with aging when looking at both sexes together. It should be noted that our measurements were of the anteromedial joint space that can be accurately measured with the cross-sectional imaging we used for this study and not of the more traditionally measured superior joint space.

The biggest limitation of this study is its cross-sectional design, as following the same patients longitudinally from age 20 to 80 years would be much more ideal. However, because the use of CT has only been around for the past 30 years, such a study is not possible at this time. We do hope, however, that a study will eventually be performed to intermittently study the same set of patients over an extended time period and confirm the changes we found in a longitudinal study. Other limitations to the present study include the location at which we measured joint space narrowing. While we were consistent with the measurement, it is not the typical superior joint space measurement that is normally measured in evaluating osteoarthritis. However, a previous study did not detect a statistically significant difference between various sites for the narrowest joint space width, so we believe this had a minimal effect on the outcome of our study.[7] Additional limitations include the possibility that our randomly selected patient population had some patients with bone deformities that we did not recognize and eliminate, but we believe that the number of patients with such issues would have been small enough to have a minimal impact. The sample size of 240 patients was also small for a population study, but the statistically significant differences that were detected were profound.

CONCLUSION

This study found enlargement of the femoral neck and head with aging and confirms our hypothesized decreased ratio of the diameter of the femoral head to the diameter of the femoral neck (relative thickening of the neck) with age, but only in men. This may be a mechanism for the development of cam-effect FAI and may be partially responsible for the increased incidence of osteoarthritis in men. Both male and female patients with radiographic signs of osteoarthritis were found to have larger femoral heads, femoral necks, and joint space narrowing compared with those without signs of osteoarthritis.

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