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Research article

Normative data on femoral version

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ABSTRACT

Femoral version is reported to vary in relation to age, gender and other patient-specific factors. Differences in femoral version are suspected to contribute to the development of hip pathology. However, normative data on pathologic hips has never been reported. To evaluate the femoral version in a large population of patients with symptomatic hip pathology treated with arthroscopy and report differences within this group based on age, gender, bony morphology and other hip-related factors. A prospectively gathered database of 1449 hips was reviewed. All patients underwent pre-operative MRI with measure of femoral version. The average femoral version of the entire population was 8.4+ 9.2°, range −23 to 63. There no statistically significant differences encountered based on age, gender, bony morphology or other hip-related factors. Across all groups, there was wide variation in the femoral version present. Among younger patients, there was trend to have a greater proportion of retroversion. Significant variation in femoral version exists in patients with symptomatic hip pathology. Although the geometry of the proximal femur is commonly described as anteverted, relative retroversion is also frequently encountered.

INTRODUCTION

The natural history of femoral anteversion is that infants are born with high femoral anteversion that decreases with age. Typically at birth, femoral anteversion is 40° and decreases to 16° by skeletal maturity [1]. There are observed population differences based on gender, with females having greater anteversion than males [2,3]. Other series suggest that additional variation exist based on ethnicity [4, 5].

Femoral version is a relevant measurement that affects hip range of motion and pathology. Significantly increased femoral anteversion affects the rotational profile of the lower extremity, leading to increased internal rotation. Retroversion of the femur may cause anterior femoroacetabular impingement. In one study, patients with decreased femoral version had worse outcomes after hip arthroscopy [6]. Other series have shown equivalent outcomes [7, 8].

The purpose of our study is to evaluate the femoral version in a large group of patients with hip conditions treated with arthroscopy. This group of symptomatic patients may differ from previously reported normative data. Further variation in femoral version may be observed within subgroups of our patient population, based on factors such as age, gender and bony morphology. Defining expected variation may provide better understanding of the pathoanatomy of the hip that leads to symptoms.

METHODS

We evaluated a series of 1449 patients from our hip arthroscopy database from 21 July 2008 to 3 August 2016. All patients participated in the American Hip Institute Hip Preservation Registry. While the present study represents a unique analysis, data on some patients in this study may have been reported in other studies. All data collection received Institutional Review Board approval. All patients in this database had a pre-operative MRI that measured femoral anteversion and were included in this study. Femoral version was measured by attending radiologists using a reference from the posterior femoral condyles superimposed over a line drawn down the femoral neck on oblique axial images [9]. Patients were stratified by age, gender, bony morphology, the capsular laxity and iliopsoas impingement. Age was subdivided in 5-year increments. Bony morphology was subdivided by the type of impingement and by acetabular coverage. The types of impingement included cam, pincer or mixed. Acetabular coverage was classified according to lateral and anterior center edge angles (LCEAs and ACEAs) as normal, borderline

dysplasia, dysplasia and over-coverage. Capsular laxity was defined as capsular closure with three or more sutures. Iliopsoas impingement included the subset of patients who had a fractional lengthening at the time of arthroscopy. Mean, standard deviation and histograms represent the data in these categories. The *t*-tests were used to compare the femoral version of males and females in each age group, and one-way analysis of variance (ANOVA) or Kruskal-Wallis tests were used as indicated based on sample variance to compare the version of multiple groups with different bony morphology.

RESULTS

There were 1449 patients with an average age of 36 years, range 12–75. The average femoral version of all patients was 8.4 ± 9.2°, range −23 to 63. This data are represented in Figs 1 and 2.

Gender

There were 980 females and 469 males. Among females, the average femoral version was 8.4 ± 9.4°, range −23 to 63. Among males, the average femoral version was 8.5 ± 9.1°, range −18 to 45. (Fig. 3)

Age

Patients were subdivided by age in 5-year increments.

There were 93 patients age 12–15 years, 58 females and 35 males. The average femoral version was 8.2 ± 7.2°, range −10 to 28, (females = 7.5, males = 9.5, $P = 0.19$) (Fig. 4).

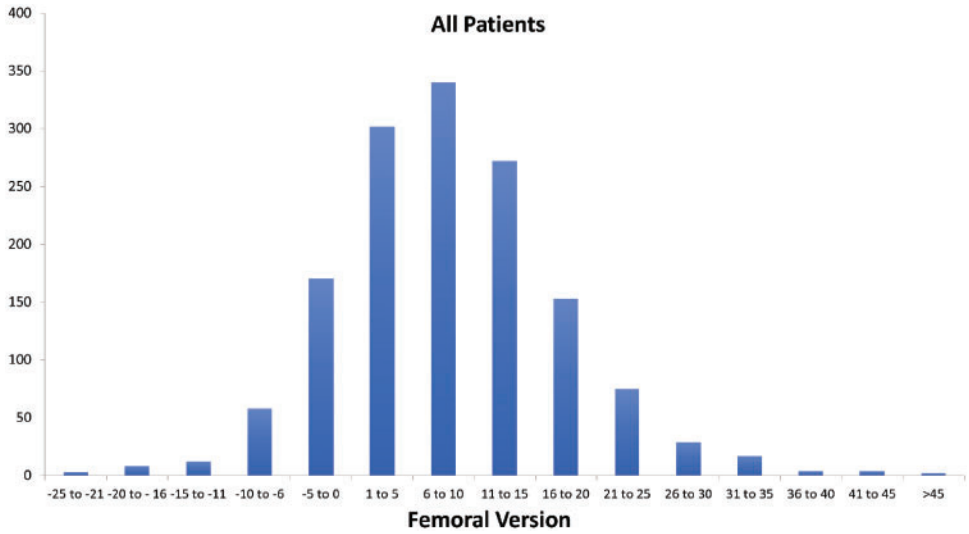

Fig. 1. Femoral version for all patients.

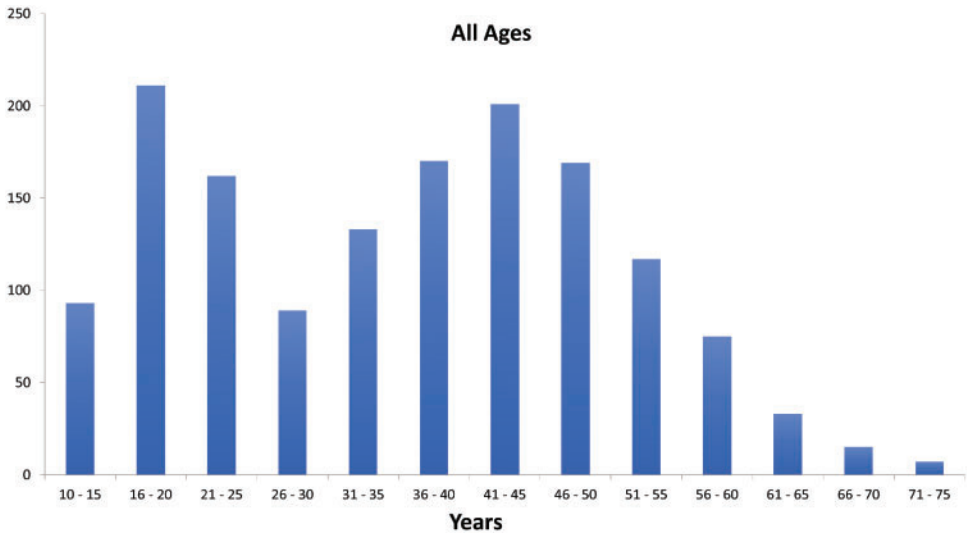

Fig. 2. Ages for all patients.

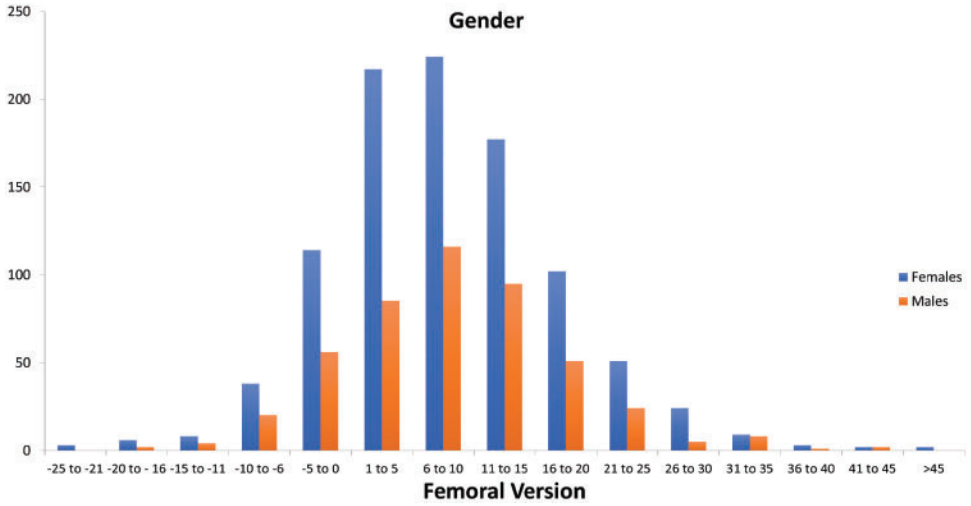

Fig. 3. Femoral version for males and females.

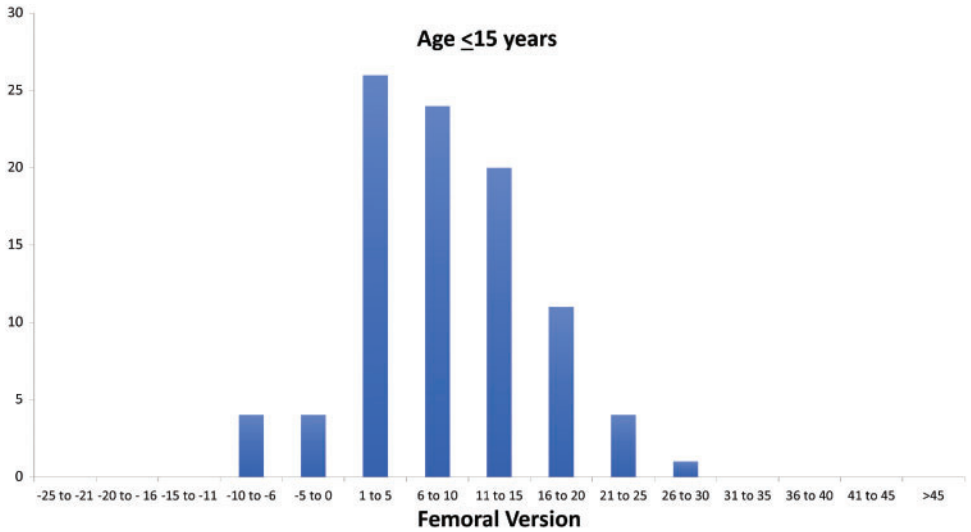

Fig. 4. Femoral version for patients age <15-years old.

There were 211 patients between 16 and 20 years, 154 females and 57 males. The average femoral version was 8.6 ± 9.8°, range −10 to 43, (females = 8.2, males = 9.9, P = 0.27) (Fig. 4).

There were 136 patients between 21 and 25 years, 93 females and 43 males. The average femoral version was 8.5 ± 9.9°, range −13 to 45, (females = 9.1, males = 7.4, P = 0.37) (Fig. 5).

There were 89 patients between 26 and 30 years, 53 females and 36 males. The average femoral version was 8.0 ± 9.4°, range −21 to 31, (females = 7.8, males = 8.4, P = 0.76) (Fig. 6).

There were 133 patients between 31 and 35, 82 females and 51 males. The average femoral version was 7.4 ± 9.0°, range −18 to 35, (females = 7.7, males = 6.8, P = 0.59) (Fig. 7).

There were 170 patients between 36 and 40, 112 females and 58 males. The average femoral version was 9.1 ± 9.5°, range −23 to 34, (females = 9.7, males = 8.0, P = 0.26) (Fig. 8).

There were 201 patients between 41 and 45, 127 females and 74 males. The average femoral version was 8.8 ± 10.4°, range −20 to 63, (females = 9.3, males = 8.0, P = 0.40) (Fig. 9).

There were 169 patients between 46 and 50, 114 females and 55 males. The average femoral version was 9.0 ± 8.7°, range −17 to 43, (females = 9.1, males = 8.8, P = 0.84) (Fig. 10).

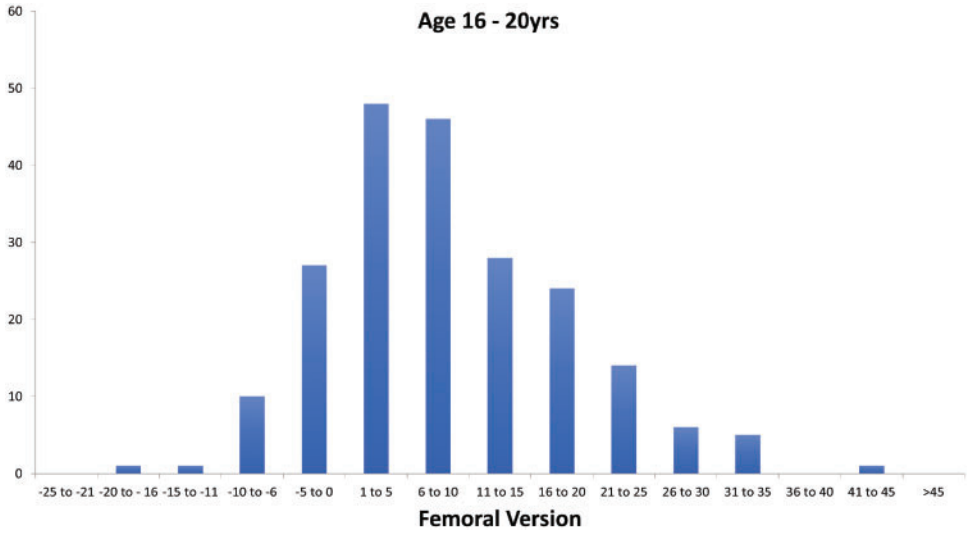

Fig. 5. Femoral version for patients age 16- to 20-years old.

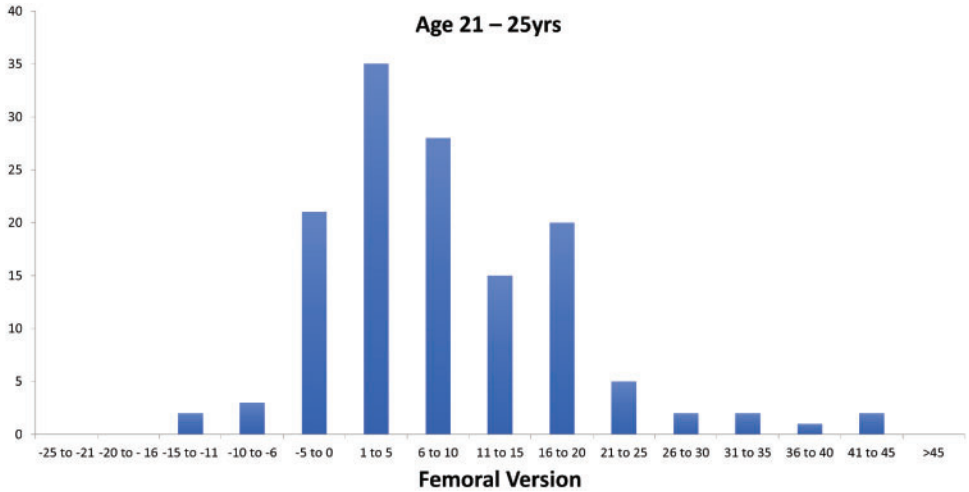

Fig. 6. Femoral version for patients age 21- to 25-years old.

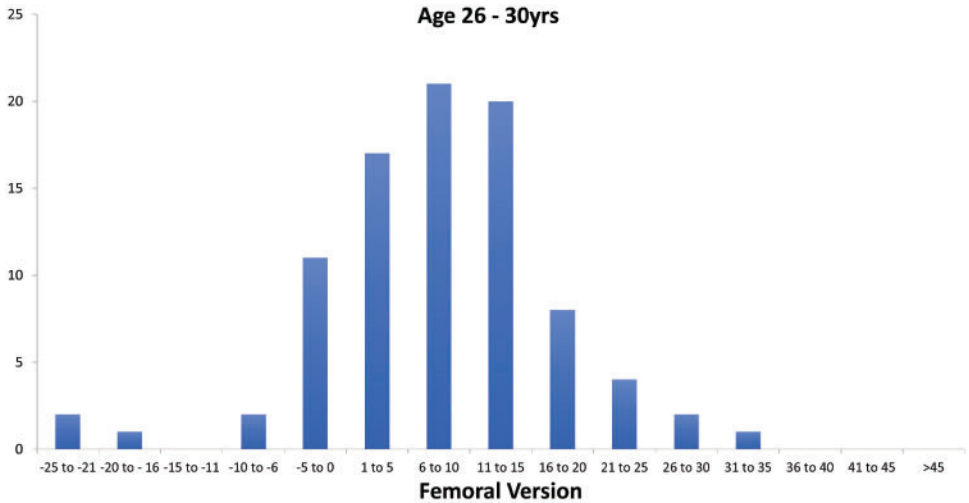

Fig. 7. Femoral version for patients age 26- to 30-years old.

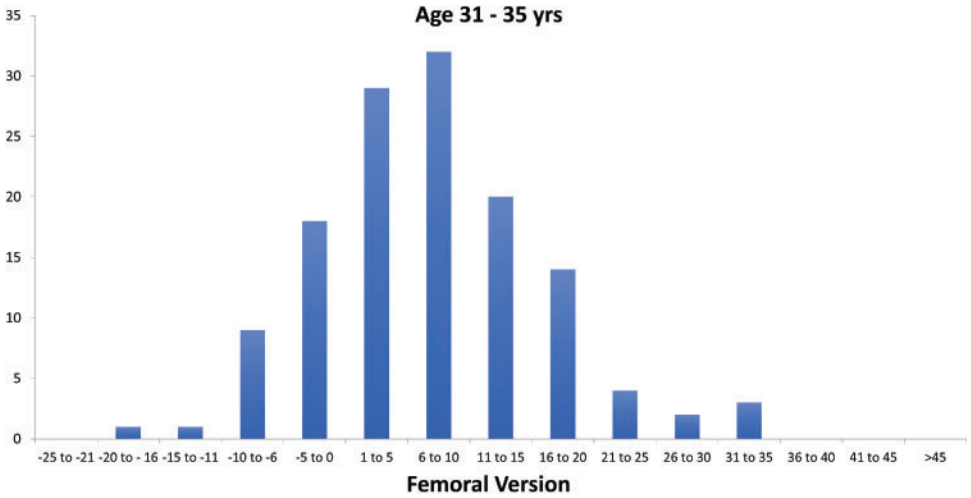

Fig. 8. Femoral version for patients age 31- to 35-years old.

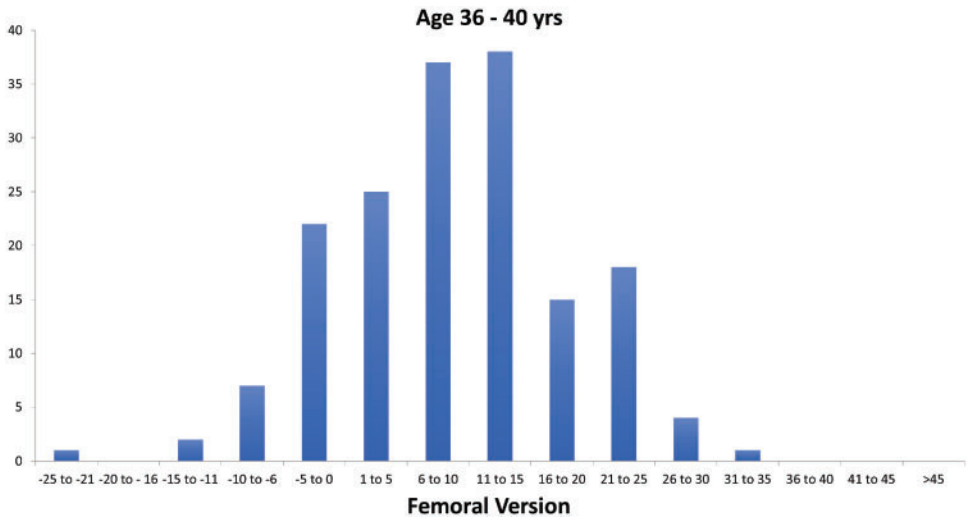

Fig. 9. Femoral version for patients age 36- to 40-years old.

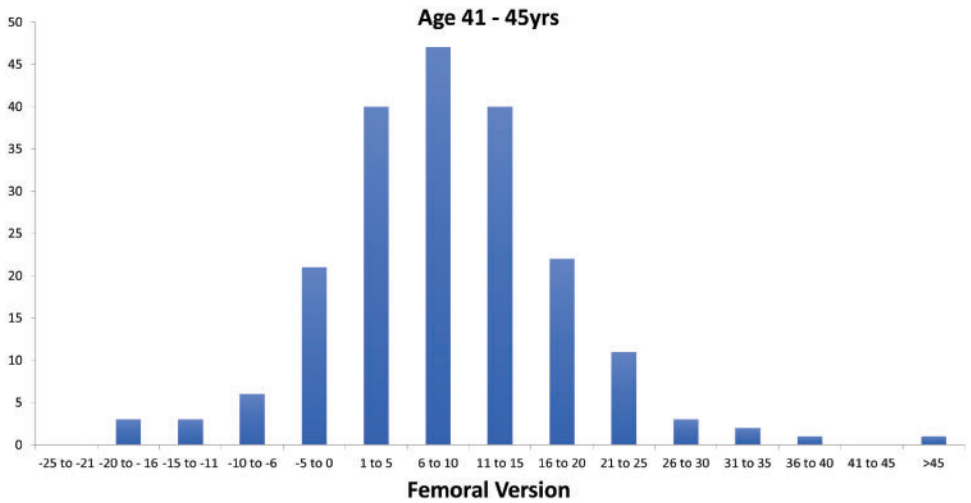

Fig. 10. Femoral version for patients age 41- to 45-years old.

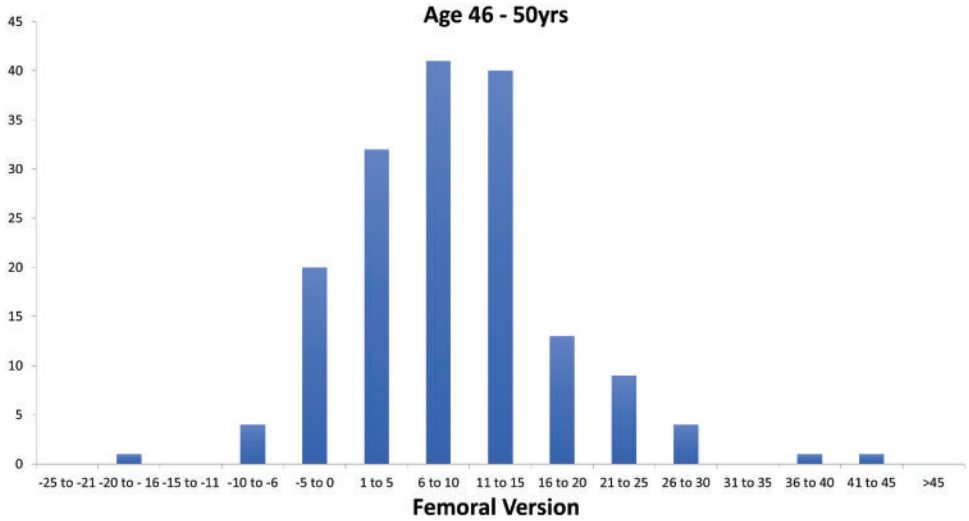

Fig. 11. Femoral version for patients age 46- to 50-years old.

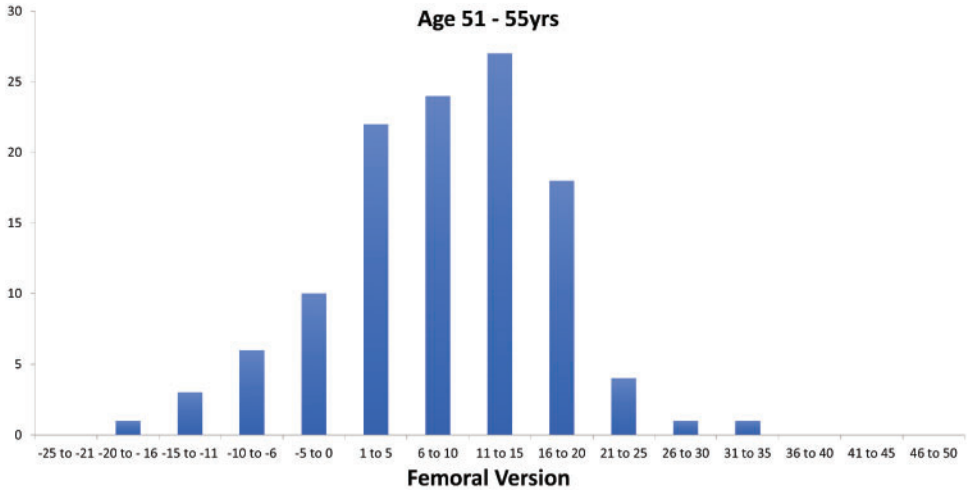

Fig. 12. Femoral version for patients age 51- to 55-years old.

There were 117 patients between 51 and 55, 89 females and 27 males. The average femoral version was 7.9 ± 8.9°, range -12–32, (females = 8.3, males = 6.4, $P = 0.31$) (Fig. 11).

There were 75 patients between 56 and 60, 58 females and 17 males. The average femoral version was 7.9 ± 8.6°, range −7 to 31, (females = 7.3, males = 9.9, $P = 0.27$) (Fig. 12).

There were 33 patients between 61 and 65, 28 females and 5 males. The average femoral version was 8.3 ± 7.5°, range −4 to 26, (females = 7.8, males = 11, $P = 0.39$) (Fig. 13).

There were 22 patients between 66 and 70, 17 females and 5 males. The average femoral version was 7.5 ± 9.4°, range −8 to 37, (females = 6.9, males = 9.2, $P = 0.64$) (Fig. 14).

There were 7 patients between 71 and 75, 4 females and 3 male. The average femoral version was 7.3 ± 9.2°, range −7 to 20, (females = 14, males = −1.7, $P = 0.008$) (Fig. 15).

Bony morphology

Complete assessments of bony morphology were not made for all patients. Therefore, we reported the results for patients with the data available.

There were 512 patients with cam morphology. Their average age was 37.5 years, range 12–68. Among them,

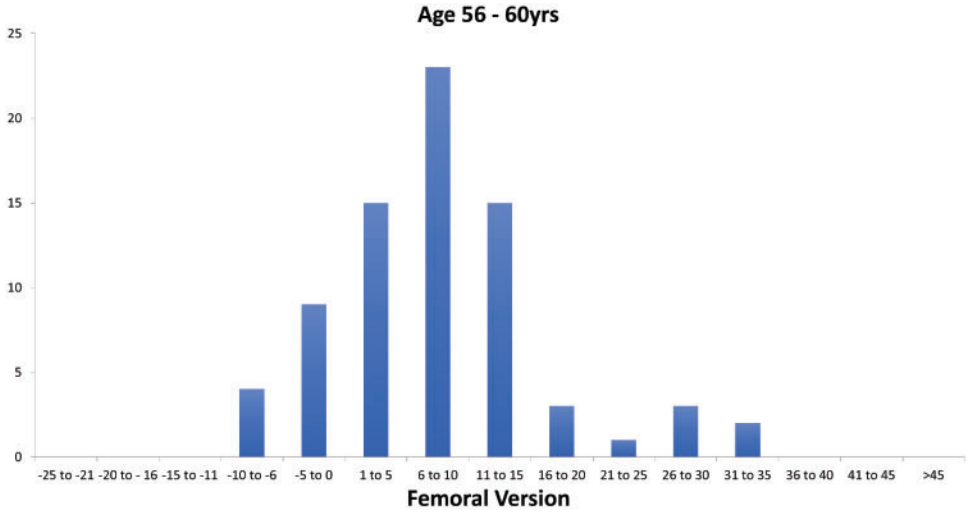

Fig. 13. Femoral version for patients age 56- to 60-years old.

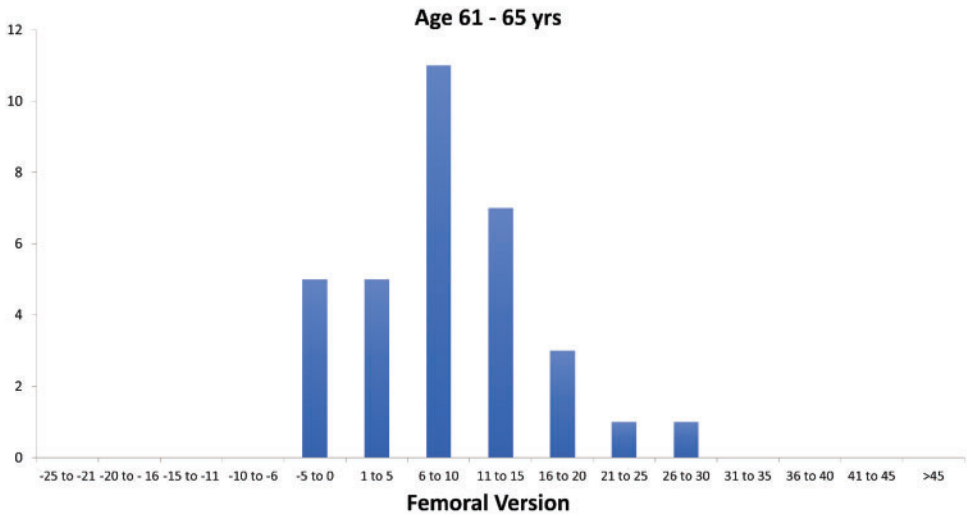

Fig. 14. Femoral version for patients age 61- to 65-years old.

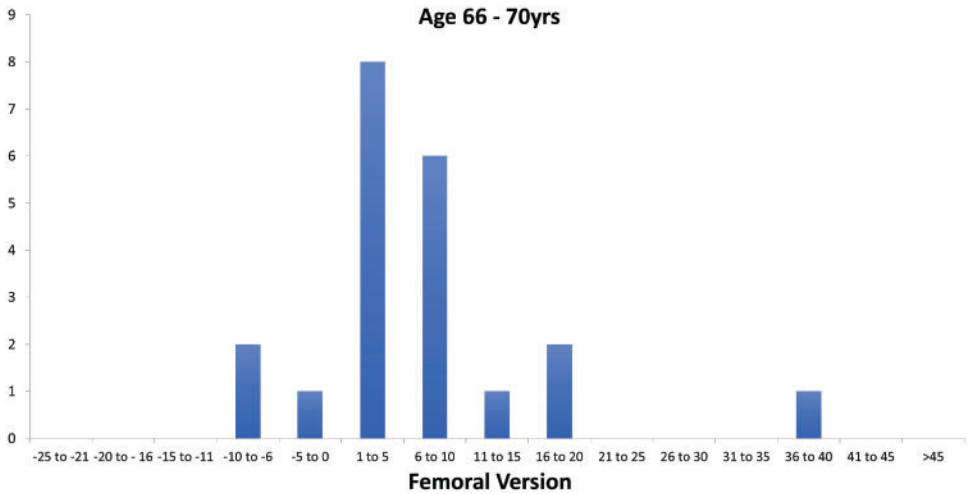

Fig. 15. Femoral version for patients age 66- to 70-years old.

there were 338 females and 174 males. The average femoral version was 8.4 ± 9.4°, range -18–63 (Fig. 16).

There were 49 patients with pincer morphology. Their average age was 31.7 years, range 12–71. Among them, there were 35 females and 14 males. The average femoral version was 8.4 ± 10.1°, range −20 to 33 (Fig. 17).

There were 612 patients with combined cam and pincer morphology. Their average age was 36.4 years, range 12–75. Among them, there were 412 females and 200 males. The average femoral version was 8.2 ± 9.3°, range −23 to 44. There was no difference in version between patients with cam, pincer, or combined morphology ($P = 0.95$) (Fig. 18).

There were 20 patients with dysplasia (LCEA <18), 83 patients with borderline dysplasia (LCEA 18–24), 487 patients with normal coverage (LCEA 25–39), and 52 patients with acetabular over-coverage (LCEA ≥ 40) (Fig. 19).

Among patients with dysplasia, there were 13 females and 7 males. The average femoral version was 8.1 ± 8.6°, range −4 to 35.

Among patients with borderline dysplasia, there were 54 females and 29 males. The average femoral version was 7.7 ± 10.0°, range −18 to 37 (Fig. 20).

Among patients with normal acetabular coverage, there were 333 females and 148 males. The average femoral version was 8.8 ± 9.7°, range −17 to 35 (Fig. 21).

Among patients with acetabular over-coverage, there were 40 females and 12 males. The average femoral version was 8.9 ± 8.5°, range −8 to 22. When classifying patients into three groups (LCEA < 25, LCEA 25–39 and LCEA ≥ 40), there were no statistically significant differences in femoral version ($P = 0.62$) (Fig. 22).

When the ACEA was used, there were 26 patients with dysplasia (ACEA < 18), 58 patients with borderline dysplasia (ACEA 18–24), 325 patients with normal coverage (ACEA 25–39) and 63 with over-coverage (ACEA ≥ 40) (Fig. 23).

Among patients with dysplasia, there were 21 females and 5 males. The average femoral version was 8.4 ± 10.9°, range −18 to 35.

Among patients with borderline dysplasia, there were 41 females and 17 males. The average femoral version was 6.9 ± 11.5°, range −15 to 44 (Fig. 24).

Among patients with normal acetabular coverage, there were 227 females and 98 males. The average femoral version was 8.5 ± 9.1°, range −18 to 38 (Fig. 25).

Among patients with acetabular over-coverage, there were 41 females and 20 males. The average femoral version was 10.1 ± 11.1°, range −12 to 49. When classifying patients into three groups (ACEA < 25, ACEA 25–39 and ACEA ≥ 40), there were no statistically significant differences in femoral version ($P = 0.32$) (Fig. 26).

There were 215 patients (159 females and 56 males) with acetabular retroversion, defined as both a cross-over sign and ischial spine sign (Fig. 27). The average femoral version was 8.2 ± 9.8°, range −18 to 44.

There were 604 patients (454 females and 150 males) who underwent iliopsoas fractional lengthening for iliopsoas impingement (Fig. 28). The average femoral version was 7.9 ± 9.2°, range −21 to 49. In comparison, there were 845 patients (526 females and 319 males) who definitively did not undergo iliopsoas fractional lengthening (Fig. 29). Their average femoral version was 8.8 ± 9.3°, range −23 to 63 ($P = 0.06$).

There were 347 patients with instability (294 females and 53 males), who required capsular plication with 3 or more sutures. The average femoral version was 8.4 ± 8.8°. In comparison, there were 618 patients (317 females and 301 males) treated with capsular release (Fig. 30). Their average femoral version was 8.7 ± 9.5°, which was not different ($P = 0.72$).

DISCUSSION

A wide range of femoral version exists, and factors such as gender and ethnicity contribute to normal variation. We reviewed a large series of patients with symptomatic hip pathology that underwent arthroscopy to identify normative femoral version within different populations, based on age, gender, and bony morphology features. The average femoral version in our series was 8.4 ± 9.2°. In general, femoral version was normally distributed with a relatively large standard deviation and wide range. Among all groups evaluated independently, no comparisons reached statistical significance or greatly deviated from the overall average. The lowest average femoral version was 6.9° in patients with ACEA < 18 and the highest was 10.1° among patients with ACEA > 40.

Femoral version is reported to be the most anteverted in infancy and decrease with age. In this series, the youngest patient was 12 and the oldest 74. A trend in decreasing femoral version with age was not observed. On the contrary, the histograms demonstrate the highest proportion of younger patients with relatively decreased femoral version. Up to age 25, the most common range of femoral version was between 0 and 5°. Patients from age 26 to 65 years most commonly had a higher femoral version. There are a few plausible reasons for this trend. Femoral anteversion is greatest in infants, and the majority of normalization occurs during ages much younger than any patients in our study. However, since our study population is symptomatic patients, it is also possible that our cohort may

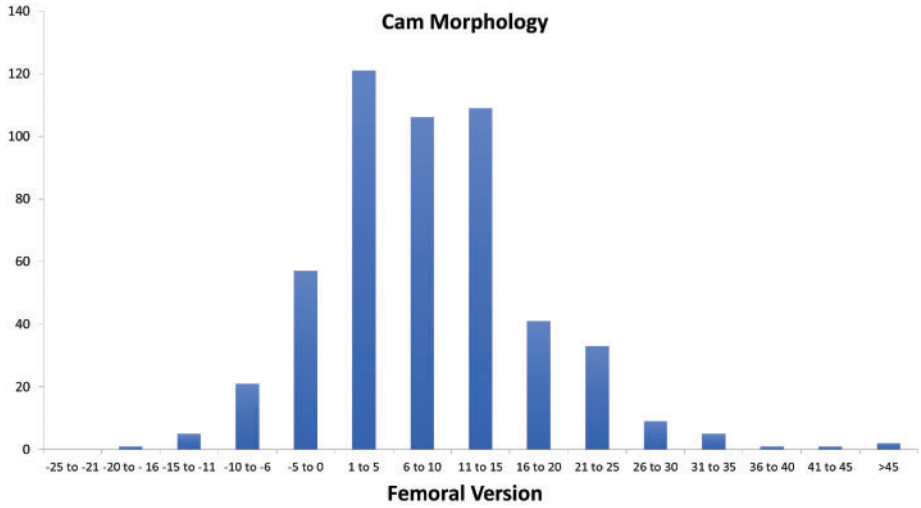

Fig. 16. Femoral version for patients with CAM bony morphology.

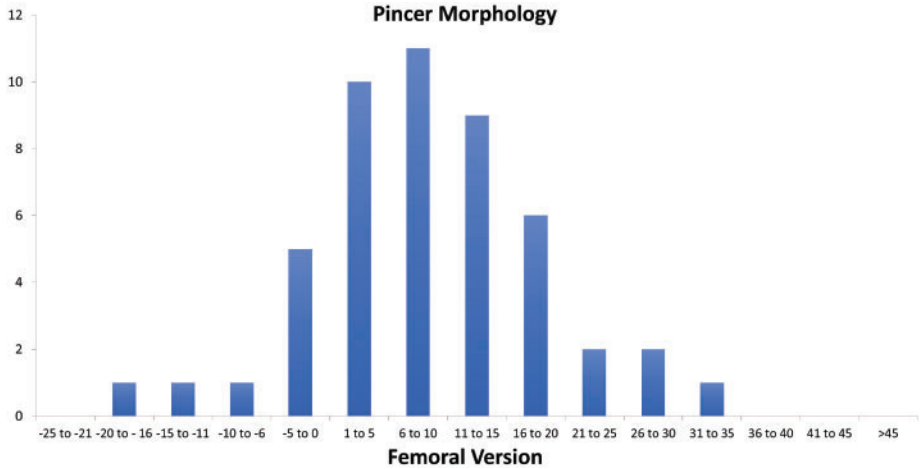

Fig. 17. Femoral version for patients with pincer bony morphology.

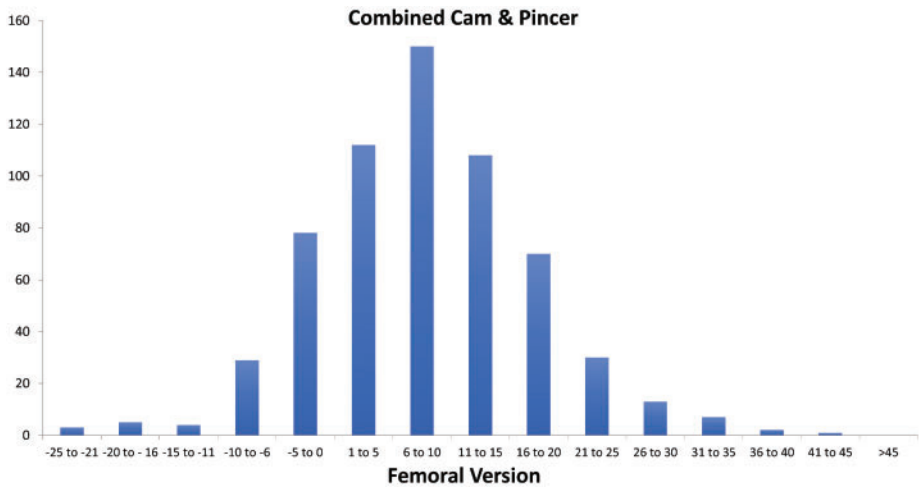

Fig. 18. Femoral version for patients with combined pincer and CAM bony morphology.

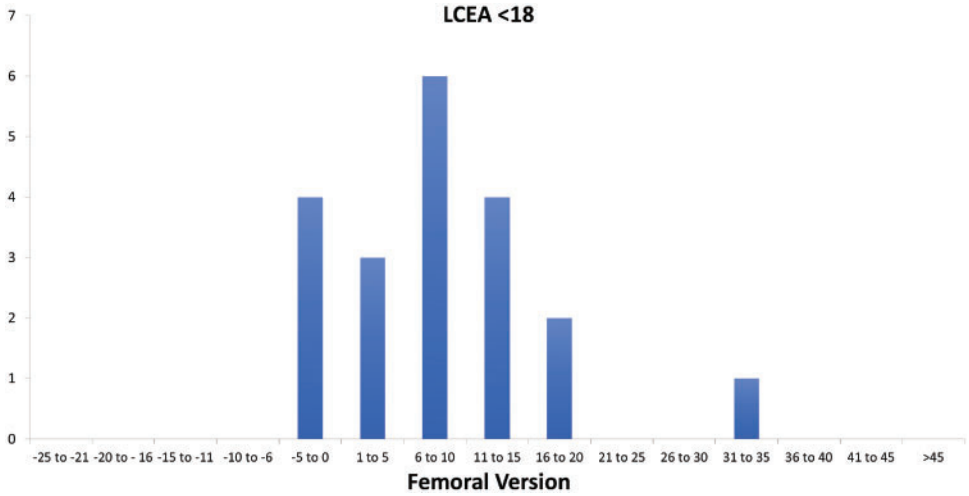

Fig. 19. Femoral version for patients that were classified as dysplastic (LCEA <18).

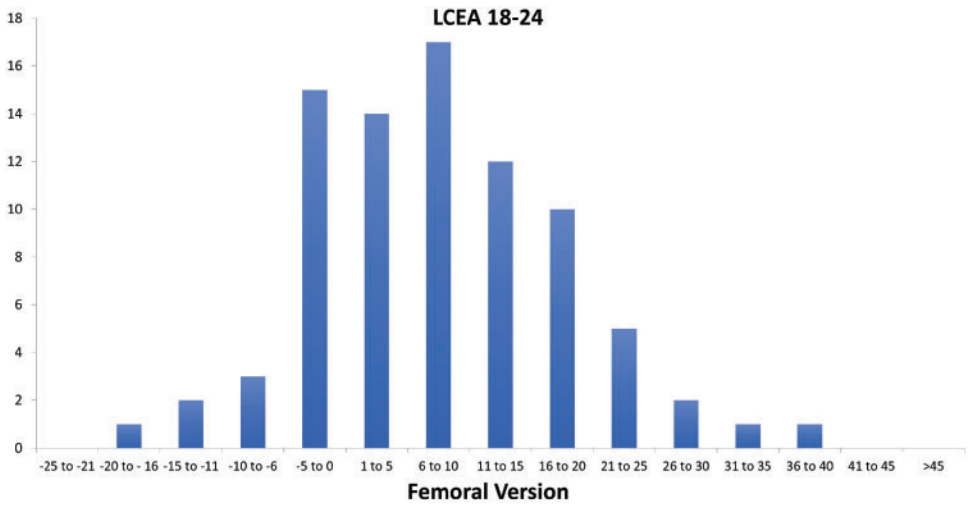

Fig. 20. Femoral version for patients that were classified as borderline dysplastic (LCEA 18–24).

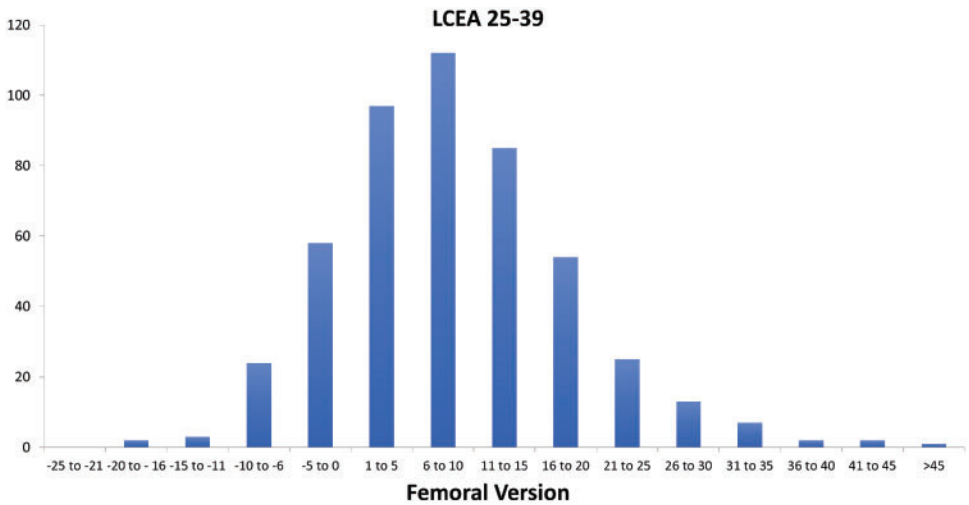

Fig. 21. Femoral version for patients that had normal acetabular coverage (LCEA 25–39).

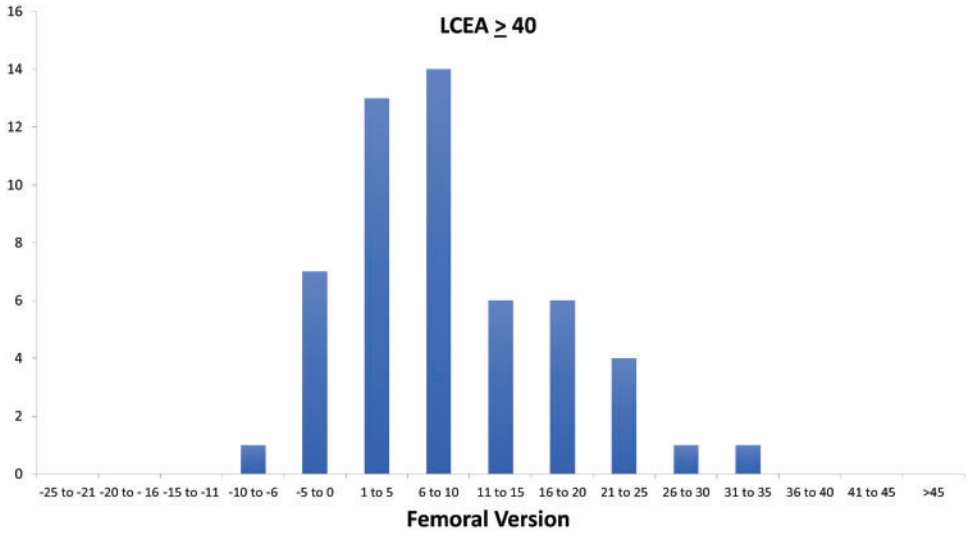

Fig. 22. Femoral version for patients that were classified as having acetabular over coverage (LCEA $\geq$ 40).

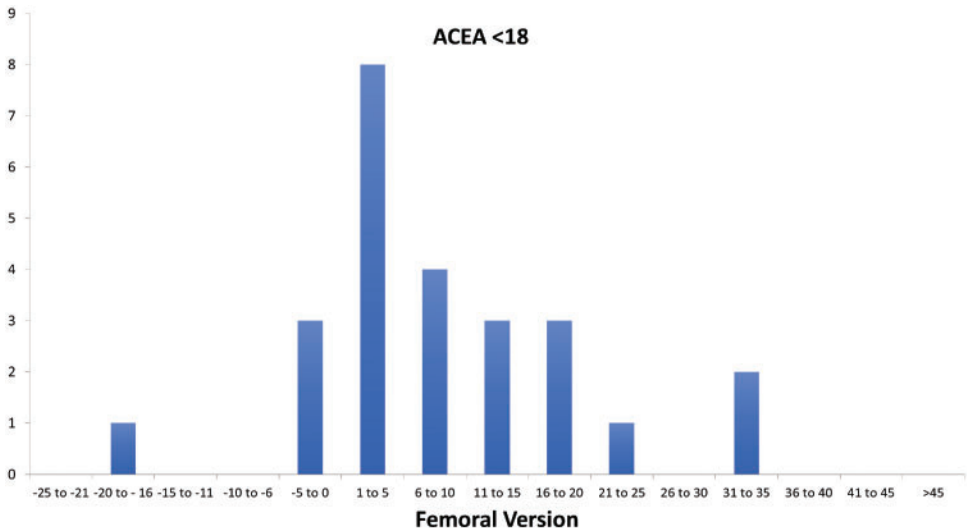

Fig. 23. Femoral version for patients that were classified as dysplastic (ACEA <18).

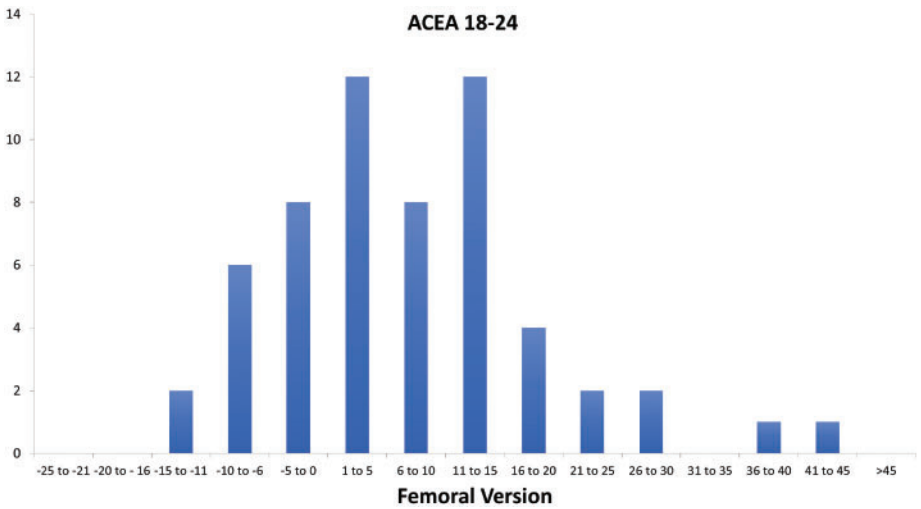

Fig. 24. Femoral version for patients that were classified as borderline dysplastic (ACEA 18-24).

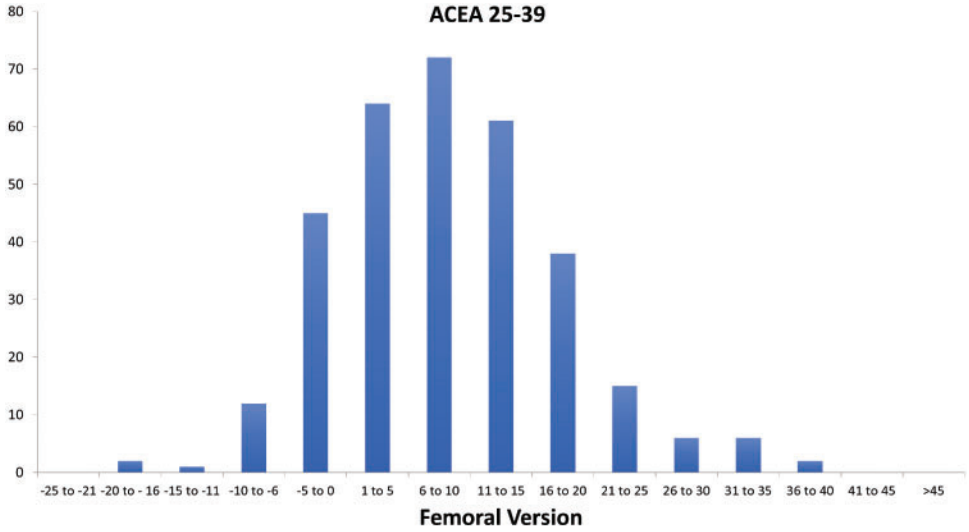

Fig. 25. Femoral version for patients with normal acetabular coverage (ACEA 25–39).

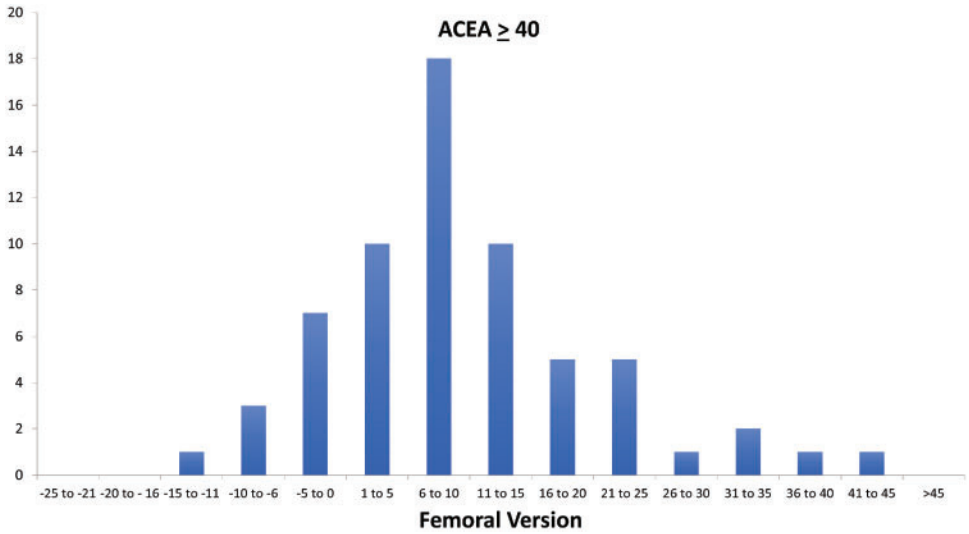

Fig. 26. Femoral version for patients with acetabular over-coverage (ACEA $\geq$ 40).

have had relatively more retroversion than the general population. Previous research has reported larger and more anterior labral tears in patients with greater femoral version [10]. We propose that relative femoral retroversion may also cause more anterior impingement, ultimately contributing to the development of pathology.

Similarly, we did not find any significant differences based on gender. Many studies report increased femoral version in women compared with men [2–4, 11]. These reported differences in femoral version are only a few degrees but reached statistical significance. Interestingly, another study by Koerner *et al.* [12] reported femoral version similar to ours. In their study of 328 patients treated for femoral shaft fracture, they found an average femoral version of 8.84 $\pm$ 9.66°. There were no gender differences observed in their study; however, they noticed a higher proportion of female patients with retroversion. Our series consisted of more females than males, which reflects that symptomatic hip pathology is more prevalent in females. The lack of gender differences in our population may also represent the fact that symptomatic patients differ from population normative data.

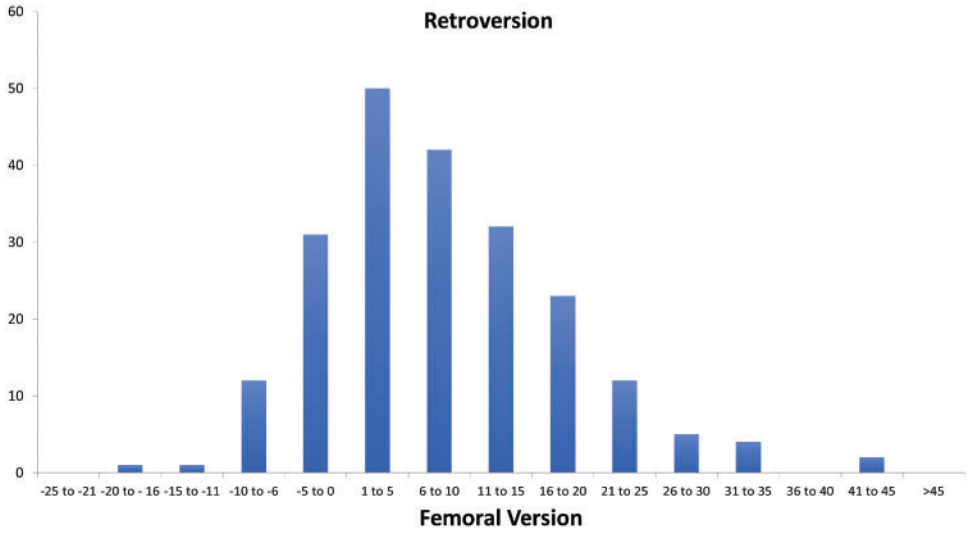

Fig. 27. Femoral version for patients with acetabular retroversion, defined by presenting with both crossover.

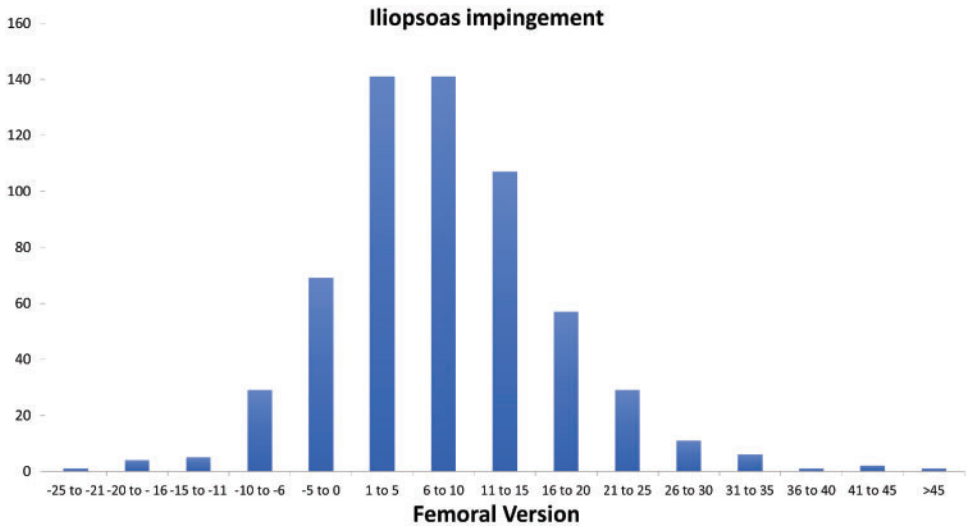

Fig. 28. Femoral version for patients who underwent iliopsoas fractional lengthening for iliopsoas impingement.

When evaluating patients based on their bony morphology, the femoral version among these groups appears relatively normally distributed. Developmental dysplasia of the hip (DDH) is often described as having increased femoral anteversion. A recent study reported increased femoral version in children with DDH compared with historically published normal values. Importantly, the authors also noted a very wide range among the hips with DDH they studied [13]. Another study evaluating cam-type femoroacetabular impingement in dysplastic hips found slightly decreased anteversion as compared with hips with pure dysplasia [14]. In our study, although there were no significant differences in version based on acetabular dysplasia, a trend toward decreased femoral version was present. We are limited in drawing further conclusions due to the relatively small numbers of dysplastic hips. Other types of bony morphology, such as acetabular retroversion, cam, pincer and combined morphology also do not appear to have any relevant changes in their femoral version.

Among other subgroups we evaluated in this study, none appeared to meaningfully deviate from the group as a whole. Previous research has identified a higher rate of iliospasos impingement among patients with increased femoral anteversion [8]. Additionally the morphology of the

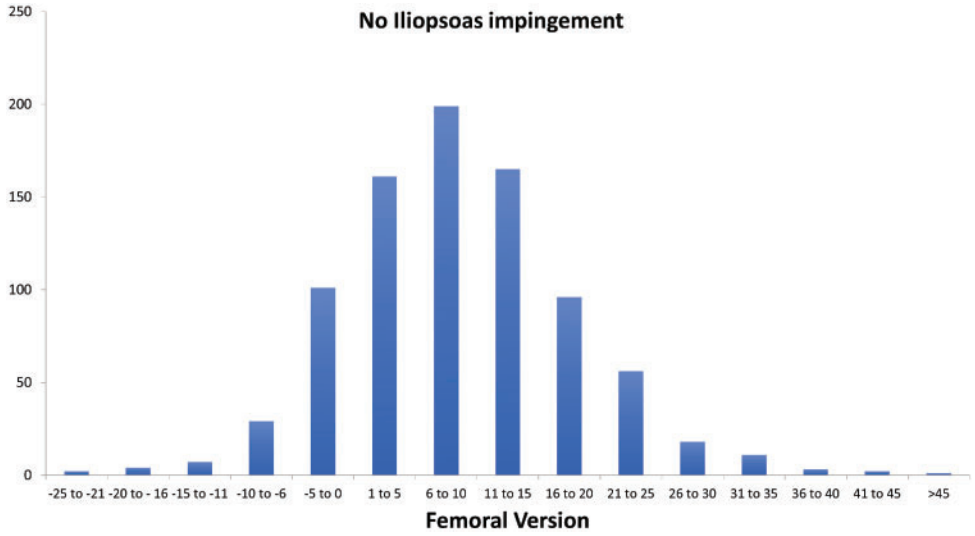

Fig. 29. Femoral version for patients who did not undergo iliopsoas fractional lengthening for iliopsoas impingement.

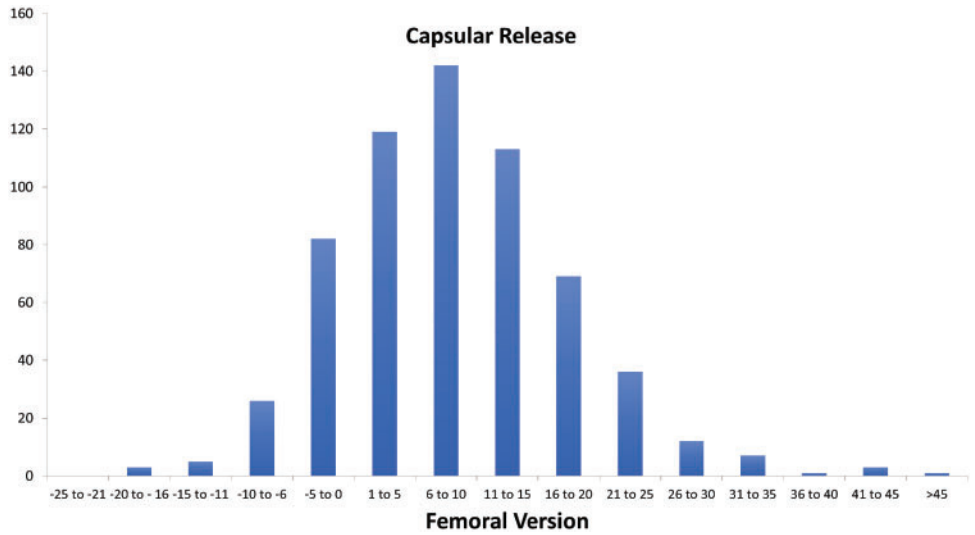

Fig. 30. Femoral version for patients that underwent a capsular release for instability.

lesser trochanter can contribute to iliopsoas impingement, specifically less trochanteric retroversion [15]. The relationship between femoral version and trochanteric version is a potential area for further evaluation. In our study, the indication for iliopsoas fractional lengthening was painful snapping, and did not find increased femoral anteversion in this group. In most cases, capsular plication with three or more sutures is performed in patients with the great ligamentous laxity and risk of hip instability. We felt this group might represent a potential group with compensatory changes in their femoral version; however, this group was also not different from the average. It should furthermore be noted, that our measurements of femoral version less than previous publications. We have previously compared MRI versus CT values in our population, and found that although highly correlated, MRI values were consistently less than CT, by an average of 8.9° [9].

LIMITATIONS

Our study is unique because it reports the version observed among a large group of symptomatic patients with hip conditions. However, it is important to consider that certain femoral version may pre-dispose the hip to the development of pathology. In our series, we found relatively higher proportion of retroversion in younger patients. The results may not be generalized to an asymptomatic population.

Additionally, consideration should be given to whether race or ethnicity affects femoral version. Given our homogenous patient population, which identified as mostly Caucasian, we were not able to evaluate these potentially relevant factors.

Our findings demonstrate a very broad distribution of femoral version across a large population with symptomatic hip pathology. Although reports of variation consistent with age, gender, ethnicity, and other factors exist, we did not find similar results among our patients.

CONCLUSION

A large variation in femoral version is encountered among patients with symptomatic hips treated arthroscopically. Patient-specific factors did not significantly affect femoral version, although relative retroversion does frequently occur in this population.

FUNDING

This study was approved by the IRB. (**IRB ID:** 5276).

CONFLICT OF INTEREST STATEMENT

Dr. Domb is a board member for American Orthopedic Foundation, American Hip Foundation, AANA Learning Center Committee, Hinsdale Hospital Foundation, and Arthroscopy Journal; Consulting Fees from Adventist Hinsdale Hospital, Amplitude, Arthrex, MAKO, Medacta, Pacira Pharmaceuticals, and Stryker; Educational funding from Arthrex, Breg, and Medwest; Food and Beverage from Arthrex, Ceterix Orthopaedics, DePuy Syntheses Sales, DJO Global, FUJIFILM SonoSite, Linvatec, MAKO Surgical Corporation, Medacta, Pacira Pharmaceuticals, Stryker, and Zimmer Biomet Holdings; Ownership Interests in Hinsdale Orthopedic Associates, American Hip Institute, SCD#3, North Shore Surgical Suites, Munster Specialty Surgery Center; Research support from Arthrex, ATI, Kaufman Foundation, Medacta, Pacira Pharmaceuticals, and Stryker; Royalties from Arthrex, DJO Global, MAKO Surgical Corporation, Stryker, and Orthomerica; Speaking fees from Arthrex and Pacira Pharmaceuticals; Travel and lodging from Arthrex, Medacta, and Stryker.

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REFERENCES

1. Fabry G, MacEwen GD, Shands AR. Torsion of the femur. A follow-up study in normal and abnormal conditions. *J Bone Joint Surg Am* 1973; **55**: 1726–38.
2. Jacquemier M, Glard Y, Pomero V *et al*. Rotational profile of the lower limb in 1319 healthy children. *Gait Posture* 2008; **28**: 187–93.
3. Hetsroni I, Dela Torre K, Duke G *et al*. Sex differences of hip morphology in young adults with hip pain and labral tears. *Arthroscopy* 2013; **29**: 54–63.
4. Hoaglund FT, Low WD. Anatomy of the femoral neck and head, with comparative data from Caucasians and Hong Kong Chinese. *Clin Orthop Relat Res* 1980; **152**: 10–6.
5. Saikia KC, Bhuyan SK, Rongphar R. Anthropometric study of the hip joint in northeastern region population with computed tomography scan. *Indian J Orthop* 2008; **42**: 260–6.
6. Fabricant PD, Fields KG, Taylor SA *et al*. The effect of femoral and acetabular version on clinical outcomes after arthroscopic femoroacetabular impingement surgery. *J Bone Joint Surg Am* 2015; **97**: 537–43.
7. Jackson TJ, Lindner D, El-Bitar YF, Domb BG. Effect of femoral anteversion on clinical outcomes after hip arthroscopy. *Arthroscopy* 2015; **31**: 35–41.
8. Ferro FP, Ho CP, Briggs KK, Philippon MJ. Patient-centered outcomes after hip arthroscopy for femoroacetabular impingement and labral tears are not different in patients with normal, high, or low femoral version. *Arthroscopy* 2015; **31**: 454–9.
9. Botser IB, Ozoude GC, Martin DE *et al*. Femoral anteversion in the hip: comparison of measurement by computed tomography, magnetic resonance imaging, and physical examination. *Arthroscopy* 2012; **28**: 619–27.
10. Ejnisman L, Philippon MJ, Lertwanich P *et al*. Relationship between femoral anteversion and findings in hips with femoroacetabular impingement. *Orthopedics* 2013; **36**: e293–300.
11. Bråten M, Terjesen T, Rossvoll I. Femoral anteversion in normal adults. Ultrasound measurements in 50 men and 50 women. *Acta Orthop Scand* 1992; **63**: 29–32.
12. Koerner JD, Patel NM, Yoon RS *et al*. Femoral version of the general population: does "normal" vary by gender or ethnicity?. *J Orthop Trauma* 2013; **27**: 308–11.
13. Sankar WN, Neubuerger CO, Moseley CF. Femoral anteversion in developmental dysplasia of the hip. *J Pediatr Orthop* 2009; **29**: 885–8.
14. Ida T, Nakamura Y, Hagio T, Naito M. Prevalence and characteristics of cam-type femoroacetabular deformity in 100 hips with symptomatic acetabular dysplasia: a case control study. *J Orthop Surg* 2014; **9**: 93.
15. Gómez-Hoyos J, Schröder R, Reddy M *et al*. Is there a relationship between psoas impingement and increased trochanteric retroversion? *J Hip Preserv Surg* 2015; **2**: 164–9.