

Comparison of Radiographic Measurements of Femoral Neck-Shaft Angle Changes Depending on Age and Gender

Merhddad Khakzad¹, Sidika Korkmaz^{1,*}, Ismail Malkoc¹

¹Düzce University, Faculty of Medicine, Department of Anatomy, Düzce, Türkiye

Abstract

Aim: The aim of this study was to analyze the morphometric changes of the femoral collodiaphyseal angle (CDA) in healthy adult individuals according to age and gender variables using computed tomography (CT) images.

Material and Methods: The study included cases from four different age groups ranging from 21 to 60 years, with an equal distribution of genders. Individuals with syndromic pathologies affecting bone morphometry, a history of hip arthroplasty, or proximal femoral fractures were excluded from the study. Morphometric measurements were performed on standard anteroposterior pelvic radiographs, taking the anatomical axis of the proximal femur as a reference.

Results: As a result of statistical analyses, it was determined that gender had a significant effect on CDA values ($p < 0.001$). The mean CDA values of female cases were found to be statistically significantly lower compared to male cases.

In terms of laterality, left femoral CDA values were observed to be significantly higher than the right side in both female ($p < 0.001$) and male ($p = 0.014$) cases. However, no statistically significant difference was found between the right ($p = 0.374$) and left ($p = 0.295$) side CDA measurements among the examined age groups.

Conclusion: The obtained data revealed that the femoral collodiaphyseal angle shows sexual dimorphism and is affected by the side (laterality) variable. However, it was concluded that this angle does not show a significant morphometric change with age in the adult population aged 21-60 years. These findings are of clinical importance for orthopedic surgical planning and implant designs related to the region.

Keywords: Femoral Collodiaphyseal Angle, Radiographic Morphometry, Proximal Femur, Sexual Dimorphism.

INTRODUCTION

The proximal femur and the hip joint play a determinative role in lower extremity weight distribution and biomechanics (1-4). The structural integrity of this region, including the femoral head and its supporting ligaments, is essential for gait stability, as detailed in comprehensive anatomical and morphometric studies (5-9). Furthermore, the surrounding pelvic anatomy significantly influences these biomechanical functions (10). The angle formed between the femoral neck and shaft, known as the femoral collodiaphyseal angle (CDA), is a critical morphometric parameter. Deviations from its physiological range alter biomechanics and are associated with various neuromuscular and congenital pathologies (11).

Accurate evaluation of the CDA is essential in orthopedic surgeries, such as total hip arthroplasty, for selecting appropriate implants and ensuring successful outcomes (12, 13). Proximal femoral morphometry

also exhibits notable sexual dimorphism; structural characteristics of the female and male pelvis influence the CDA, resulting in significant gender variations (14-17).

Despite its clinical significance, comprehensive studies evaluating the age and gender-related changes of the CDA using precise cross-sectional imaging remain limited. Therefore, this study aims to analyze the morphometric variations of the CDA according to age and gender variables in healthy adults aged 21-60 years using computed tomography (CT) images.

MATERIALS and METHODS

This retrospective study was conducted following the approval of the Düzce University Non-Interventional Health Research Ethics Committee (Decision No: 2023/164). Study data were obtained by scanning

*Corresponding Author: Sidika Korkmaz sidikakaraketir4@gmail.com

Cite as: Khakzad M, Korkmaz S, Malkoc I. Comparison of Radiographic Measurements of Femoral Neck-Shaft Angle Changes Depending on Age and Gender. Dyna Med Theories 2026;2(2):88-95

the images of individuals who applied to the Düzce University Research and Practice Hospital Department of Radiology archives between 20.10.2023 and 20.06.2024. The study sample consisted of a total of 480 cases aged between 21-60 years with an equal gender distribution (n=240 females, n=240 males). The cases were divided into four groups comprising the age ranges of 21-30, 31-40, 41-50, and 51-60 years, with an equal number of individuals (60 females, 60 males) in each group. Patients with syndromic pathologies affecting bone morphometry, those who had undergone hip replacement surgery, and those with femoral head fractures were excluded from the study.

CDA measurements were performed using Computed Tomography (CT) images on the Picture Archiving and Communication System (PACS). The Proximal Femur Axis (PFE) method defined in the literature was used for measurement. In this method, the femoral shaft axis (F) was formed by joining the midpoints (P, Q, R) determined on the medial and lateral cortices of the proximal diaphysis. The femoral neck axis (E) was determined by joining the center of the femoral head (M) and the midpoint (O) of the intertrochanteric line drawn from the most prominent points of the greater and lesser trochanters. The angle between these two axes (F and E) was recorded as the CDA (Figure 1), (11, 18-20). To ensure the reliability of the morphometric evaluations, measurements were independently performed by one observer. The observer were blinded to the demographic data (age, gender) and the clinical information of the cases. To calculate intra-observer reliability, the primary investigator repeated the measurements on a randomly selected subset of 48 cases four weeks after the initial assessment.

To evaluate potential spinal curvatures, the Cobb angle was measured on the available anteroposterior chest radiographs. The measurement was performed by identifying the most tilted vertebrae at the superior and inferior limits of the curve. Lines were drawn parallel to the superior endplate of the upper end vertebra and the inferior endplate of the lower end vertebra. The angle formed by the intersection of lines drawn perpendicular to these two parallel lines was recorded as the Cobb angle (Figure 2).

Statistical Analysis

Statistical analyses were performed using the SPSS 22.0 package program and special macros. Descriptive statistics of the data were presented as mean, standard deviation, and percentage. The conformity



Figure 1. CDA measurement relative to the proximal femur axis (11).

of quantitative variables to normal distribution was examined using Skewness and Kurtosis coefficients and the Shapiro-Wilk test, while the homogeneity of group variances was checked with the Levene test. Factorial ANOVA was used to determine the effect of different factors on quantitative variables, and the Paired samples t-test was used for intragroup comparisons. A p-value of <0.05 was considered statistically significant in all analyses. Inter-observer and intra-observer reliability of the CDA measurements were evaluated using the Intraclass Correlation Coefficient (ICC) with a two-way mixed-effects model and absolute agreement type. ICC values were interpreted as: <0.50 poor, 0.50-0.75 moderate, 0.75-0.90 good, and >0.90 excellent reliability.



Figure 2. Example radiographic measurement.

RESULTS

A total of 480 individuals, equally distributed as 240 females and 240 males, were included in the study. Their right and left collodiaphyseal angles (CDA) were evaluated separately across four age groups with 10-year intervals (21-30, 31-40, 41-50, 51-60). Sixty males

Right leg CDA values were statistically significant according to gender, and the value measured in females was lower compared to males ($p < 0.001$) (Table 1). There was no statistically significant difference in right leg CDA values according to age group ($p = 0.374$) (Table 1).

Table 1 | Combined values of right leg CDA, age, and gender

Age	Female (Mean)	Female (SD)	Male (Mean)	Male (SD)	Total (Mean)	Total (SD)	p
21-30	125.79	3.90	127.76	3.77	126.77	3.95	0.812* / 0.374**
31-40	126.23	4.17	128.83	4.44	127.53	4.48	
41-50	126.73	5.50	128.67	5.56	127.70	5.59	
51-60	126.24	5.33	129.18	5.06	127.71	5.38	
Total	126.25	4.76	128.61	4.76			<0.001***

> *: Gender and age group interaction effect, **: age group effect, ***: gender effect

and 60 females were included equally in each age group. Reliability analysis demonstrated excellent agreement for the measurements. The inter-observer Intraclass Correlation Coefficient (ICC) was 0.89 (95% CI: 0.82–0.93), and the intra-observer ICC was 0.94 (95% CI: 0.89–0.97).

There was a statistical difference in left leg CDA values according to gender, and the value measured in females was significantly lower ($p < 0.001$). There was no statistically significant difference in left leg CDA values according to age group ($p = 0.295$) (Table 2).

Table 2 | Combined values of left leg CDA, age, and gender

Age	Female (Mean)	Female (SD)	Male (Mean)	Male (SD)	Total (Mean)	Total (SD)	p
21-30	126.16	3.83	3.68	3.77	126.99	3.83	0.774* / 0.295**
31-40	126.46	3.89	4.53	4.44	127.81	4.42	
41-50	126.92	5.56	5.45	5.56	127.89	5.57	
51-60	126.75	5.18	5.30	5.06	128.07	5.39	
Total	126.57	4.66	4.80	4.76			<0.001***

>*: Gender and age group interaction effect, **: age group effect, ***: gender effect

There was a statistically significant difference between the right and left leg CDA values measured in females ($p<0.001$); the left leg CDA value was higher compared to the right leg CDA value. When examining the right and left leg CDA values in males, there was a statistically significant difference as observed in females ($p=0.014$); the left leg CDA was higher compared to the right leg CDA (Table 3).

The effect of existing spinal curvatures on CDA was evaluated using Pearson correlation analysis. When all patients were included in the analysis, there was no statistically significant difference (Table 5).

The situation was similar when only female individuals were evaluated (Table 6).

Table 3 | Both leg CDA values according to gender

Gender	Right Leg CDA (Mean)	Right Leg CDA (SD)	Left Leg CDA (Mean)	Left Leg CDA (SD)	p
Female	126.25	4.76	126.57	4.66	<0.001
Male	128.61	4.76	128.81	4.80	0.014

Considering that the asymmetry between the extremities might originate from scoliosis, the Cobb angles of 43 patients whose chest radiographs were accessible were measured. No individuals were diagnosed with scoliosis, and no statistically significant difference was found between males and females (Table 4).

When the relationship between the Cobb angle and CDA of male individuals was evaluated, a statistically significant positive correlation was observed on the right side (Table 7).

Table 4 | Cobb angles according to gender

Parameter	Male (Mean)	Male (SD)	Female (Mean)	Female (SD)	p
Angle	5.388	2.150	5.396	2.073	0.989

Table 5 | Relationship between Cobb angle and CDA in all individuals

Variable	Angle	CDA (Left)	CDA (Right)
Variable	r	-	
	p	-	
CDA (Left)	r	0.150	-
	p	0.336	-
CDA (Right)	r	0.142	0.976
	p	0.364	<0.001

Table 6 | Relationship between Cobb angle and CDA in female individuals

Variable	Angle	CDA (Left)	CDA (Right)
Variable	r	-	
	p	-	
CDA (Left)	r	-0.027	-
	p	0.895	-
CDA (Right)	r	-0.059	0.990
	p	0.769	<0.001

Table 7 | Relationship between Cobb angle and CDA in male individuals

Variable		Angle	CDA (Left)	CDA (Right)
Variable	r	-		
	p	-		
CDA (Left)	r	0.453	-	
	p	0.078	-	
CDA (Right)	r	0.535	0.952	-
	p	0.033	<0.001	-

DISCUSSION

This study aimed to examine the changes in CDA according to age and gender using radiographic images. As a result of the evaluations conducted in our study, it was found that there is no significant difference in CDA depending on age. These findings are consistent with previous studies. In a study conducted by Jiang et al. in 2015, two sample groups were created as under 60 and over 60 years of age, and measurements were taken in 466 individuals. As a result, they stated that CDA is not age-related. Nissen et al., in a 2005 study on the radiographic images of 249 healthy individuals, found that CDA increased with age in male individuals, while no significant finding was encountered in females. In a study by Gilligan et al. in 2013, the relationship of CDA with climate, clothing, lifestyle, gender, age, and right-left differences was investigated by examining 8,271 femurs belonging to 100 different human groups. The mean CDA value was found to be 127°, which is lower than the frequently stated value of 135° in the literature. In relation to climate, the angle was found to be higher in warm regions and lower in cold regions. A slight difference was observed between the right and left legs, with a statistically small asymmetry indicating that the right leg had a slightly lower angle, but no significant differences were found in terms of gender and age. It was concluded that cultural factors (e.g., clothing usage) may be effective in the developmental differences of this angle (21-23).

When we evaluated CDA according to gender in our study, it was determined that there was a significant difference; this angle was lower in females and higher in males. The clinical implications of these morphometric findings are particularly critical for orthopedic surgery. In procedures such as total hip arthroplasty (THA) and proximal femoral fracture fixation, precise knowledge of the patient's native CDA is essential for restoring normal hip biomechanics. Using an implant with an

inappropriate neck-shaft angle can lead to severe complications, including altered abductor muscle tension, leg length discrepancy, increased risk of dislocation, and premature implant wear. Furthermore, the significant gender differences observed in our study emphasize that 'one-size-fits-all' orthopedic implants may be suboptimal. The finding that males generally have a wider CDA highlights the necessity for gender-specific implant designs and tailored preoperative templating to ensure optimal load distribution and long-term surgical success. Looking at the literature, there are studies supporting our work. Mitra et al., in a study conducted in 2014, examined the radiographic images of 200 individuals and documented an obvious difference in this angle between females and males, with the CDA being larger in males compared to females. Based on this significant difference, they argued that gender determination could be made through CDA. Bagaria et al. stated in their 2010 study that ethnicity and geographical location affect this angle. They compared the available data of Western society with data from the Indian population and, by performing radiographic measurements of 211 individuals, determined that CDA was greater in males compared to females. Based on this study, it was argued that implants suitable for the Indian population should be developed. In a study conducted by PS Igbigbi in 2003, radiographic images of 860 East African individuals were evaluated, and a significant difference was found between females and males. The CDA of East African individuals was documented for the first time, and the angle was calculated to be wider in males. Tahir et al., in their study on a bone collection belonging to 200 males and 120 females, evaluated the collodiaphyseal angle as 127°±3.4 in females and 137°±3.9° in males, determining a significant difference according to gender, with the CDA being greater in males compared to females (18, 24-26).

As a result of the analyses, it was determined that this angle was larger in male individuals compared to females. This difference initially caught our attention and was re-evaluated in light of the literature. When evaluated from an anatomical and biomechanical perspective, it is known that the bone structure of male individuals is generally larger and heavier. This structural characteristic means that the body places more load on the lower extremities. Accordingly, the larger CDA in males is thought to be an anatomical adaptation against the increased load-bearing requirement. From a biomechanical perspective, a wider CDA allows for a more even distribution of mechanical loads across the femoral neck, thereby increasing load-bearing capacity and minimizing stress concentration. Conversely,

narrower angles increase perpendicular shear forces, which can elevate the risk of regional fractures. It is also stated in the literature that femoral neck fractures, which are common especially in elderly male individuals, may be associated with angle changes. In conclusion, it is thought that the gender-related CDA difference observed in our study is compatible with the load-bearing requirements specific to male anatomy, and this difference plays a significant role biomechanically (27, 28).

As a result of the evaluations made on right and left leg CDAs in our study, it was determined that there was a significant difference in both females and males, and the left CDA was found to be higher compared to the right CDA. There are also literature sources contrasting with the results obtained in our study. In a cross-sectional radiographic study conducted by Roy et al. in 2014, 102 elderly individuals from East India were examined, and no significant difference was found in measurements between the right and left sides. They attributed this to the limited measurement methods of their study. Skaria et al., in a study conducted in India in 2022, worked on 300 dry bones of unknown gender and found the right femur CDA to be higher than the left CDA. In order for total hip replacement surgeries to be performed accurately and successfully, an attempt was made to determine the extent to which this angle varies between races and genders. These angle variables in that population should be considered for preoperative planning (29, 30).

In this study, the left CDA was found to be larger compared to the right leg in both male and female individuals. As a secondary evaluation, scoliosis was considered as one of the possible causes of this asymmetry, and accordingly, the chest radiographs of the individuals were examined retrospectively. However, the radiographs of some individuals could not be accessed, and in the radiographs of the 43 individuals obtained, it was observed that the Cobb angles were below 10° . As is known, for a diagnosis of scoliosis, the curvature in the spine must be at least 10° . Therefore, no individual diagnosed with scoliosis was found in the sample, and it was understood that the existing spinal curvatures were not at the level of clinical scoliosis. These results revealed that the left leg CDA being larger than the right leg cannot be explained by the presence of scoliosis. However, it is thought that such bilateral differences may pave the way for postural disorders and the subsequent development of scoliosis, especially during the growth period or in cases where age-related musculoskeletal balance deteriorates.

Therefore, although this difference in CDA is not a direct consequence of scoliosis, it should be considered a potential risk factor (31, 32).

The relationship between scoliosis and CDA was evaluated by Pearson correlation analysis. When all individuals were analyzed together, no statistically significant relationship was found between the Cobb angle and CDA. In the analyses performed in gender subgroups, no significant correlation was detected in female individuals in a similar manner. However, when only male individuals were examined, a statistically significant positive correlation was detected between the Cobb angle and the right leg CDA. This finding suggests that spinal curvatures in males may affect lower extremity biomechanics, especially the right side, more prominently. Possible reasons for this situation may include the fact that males have a genetically and anatomically larger bone structure, and accordingly, spinal curvatures form more distinct compensatory mechanisms. In addition, the significance of the right-sided relationship may be associated with factors such as the dominant side usage habits of the individuals, the direction of the spinal curvature (convexity side), and load distribution. However, for these hypotheses to become clear, further studies with larger samples that include the direction of scoliosis, extremity dominance, and musculoskeletal balance mechanisms are required. Furthermore, evaluating the Cobb angle in only 43 out of 480 patients creates a potential selection bias. Therefore, this subgroup analysis should be interpreted cautiously due to limited sample size.

There are several limitations to this study that should be acknowledged. First, the study has a retrospective design and was conducted at a single center, which may limit the generalizability of our results to broader populations. Second, although the evaluations were performed carefully, inherent radiological measurement errors—such as those arising from slight variations in patient positioning or the manual identification of anatomical reference points—cannot be entirely completely ruled out. Finally, as mentioned, the evaluation of the Cobb angle was restricted to a limited subgroup of 43 patients due to data accessibility. This lack of data creates a potential selection bias, meaning the subgroup analysis regarding spinal curvatures should be interpreted with caution.

➤ CONCLUSION

In conclusion, the primary findings of this study demonstrate that the femoral collodiaphyseal angle exhibits significant sexual dimorphism, with males having a wider CDA compared to females. This is likely a biomechanical adaptation for increased load-bearing requirements. While the CDA does not show significant age-related changes in the adult population (21-60 years), a notable left-right asymmetry exists. Although our secondary evaluation suggests that spinal curvatures may have a minor influence on right leg biomechanics in males, extremity asymmetry could not be primarily attributed to scoliosis in the general population. Ultimately, recognizing these gender-specific and asymmetrical morphometric variations is of critical clinical importance for precise preoperative planning and the design of tailored orthopedic implants.

Acknowledgments: The authors have no financial support or specific acknowledgments to declare for this study.

Ethical Approval: Ethical approval for this study was obtained from the Non-Interventional Clinical Research Ethics Committee of Düzce University (Decision No: 2023/164). All procedures were performed in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments.

Author Contributions: Idea/Concept: M.K., S.K.; Design: M.K., S.K.; Supervision: M.K., S.K.; Resources: M.K., S.K.; Materials: M.K., S.K., İ.M.; Data Collection and/or Processing: M.K., S.K., İ.M.; Analysis and/or Interpretation: M.K., S.K., İ.M.; Literature Review: M.K., S.K., İ.M.; Written by: M.K., S.K., İ.M.; Critical Review: M.K., S.K., İ.M.

Conflict of Interest: The authors declare that they have no conflict of interest.

Financial Disclosure: No funding was used in the preparation of this study.

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