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Adult acetabulo – pelvic parameters in Turkish society: A descriptive radiological study

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ABSTRACT

Objective: The aim of this study was to measure the prevalences of the acetabular index, collodiaphyseal angle, CE angle, articulo-trochanteric distance, cross-over sign and posterior wall sign in healthy Turkish people, in order to shed light on the production of orthopedic medical products.
Methods: In this study, both hips (a total of 3960 hips) of 1980 individuals (1178 males, 802 females) from nine different cities between the ages of 18 and 65 years were measured and statistically analyzed.
Results: The right articulo-trochanteric distance of all participants was 19.67 ± 4.52 mm and the left articulo-trochanteric distance was 19.10 ± 4.58 mm. The CE angle was 35.11°±7.41° in the right hip and 35.37°±6.76° in the left hip. The acetabular index was 37.58°±5.30° in the right hip and 37.80°±4.82° in the left hip. The collodiaphyseal angle was 138.60°±8.27° in the right and 137.84°±8.01° in the left hip. The prevalence of cross-over sign in the right hip was 6.46% and 6.66% for the left hip. The prevalence of posterior wall sign was 4.24% for the right hip and 4.19% for the left hip.
Conclusion: This study has provided prevalence values of cross-over sign, posterior wall sign, acetabular index, collodiaphyseal angle, CE angle and articulo-trochanteric distances of a healthy Turkish population between the ages of 18 and 65 years.

The morphologic evaluation of the hip joint is done by plain radiologic examination. While various methods were described for measurements of the hip joint, certain methods and hip joint parameters are most frequently used in clinical practice. These were described by various authors and include CE angle of the hip, acetabular index and collodiaphyseal angle,[1–5] along with articulo-trochanteric distance, cross-over sign, and posterior wall sign, which provide information on the three-dimensional spatial position of the hip joint.[6–8]

The aim of this study was to delineate the orthopedic problems of hip origin that the Turkish population will experience in the future and to evaluate the acetabular and pelvic parameters in order to shed light on the design of hip implants.

Patients and methods

In this study, we evaluated the pelvic anteroposterior roentgenograms of 380 patients aged 18–65 years admitted to our hospital (Ankara) and the pelvic anteroposterior roentgenograms for 200 patients from each of the following eight cities; Adiyaman, Afyonkarahisar, Bursa, Izmir, Istanbul, Konya, Trabzon, and Van. In routine trauma X-ray studies, CE angles of both hips, the acetabular index, collodiaphyseal angle, articulo-trochanteric distance, cross-over sign, and posterior wall sign parameters were evaluated for 1980 patients (1178 males, 802 females; mean age: 39.6 years, range: 20–65 years) who were admitted at our Emergency Department and in whom no pathological findings were detected.

Patients who had pelvic trauma, pelvic rotation, scoliosis or thoracolumbar deformity, coxarthrosis, pelvic or femoral prostheses which had been implanted for any reason, developmental hip luxation sequela, and dissymmetry of the obturator foramen in the

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roentgenogram were excluded from this study. In order to detect the obturator foramen dissymmetry, the largest diameters of the two perpendicular obturator foramen were measured and cases with a total difference >2 mm were excluded. Measurements were done manually using a goniometer in 466 cases and digitally in 1514 cases.

The hip joint was evaluated on the anteroposterior pelvic roentgenograms. In order to obtain a standard evaluation, roentgenograms were taken from a 100 cm constant distance, and the X-rays were centralized on a plane 5 cm from the symphysis pubis.[9]

An investigator measured the roentgenogram by goniometry and another investigator repeated the measurement next day for control. Thus, all roentgenograms were cross-checked. PACS images in the Hospital Data System were digitally measured using an Oracle database.

The CE angle is the angle formed by a line drawn perpendicular to a baseline that passes through the center of the femoral heads and a line connecting the center of the femoral head and the superior border of the acetabulum.[2] In this study, the center of the femoral head was measured using plastic transparent templates containing concentric circles. The acetabular angle is the horizontal line connecting the right and left pelvic tear drops and the lateral border of the acetabular roof and inferior pelvic tear drop.[10] The collodiaphyseal angle is the angle between the long axis of the femur and the long axis of the femoral neck.[11] The articulo-trochanteric distance is measured between a line passing from the upper edge of the femoral head, perpendicular to the femoral longitudinal axis, and another line from the upper point of the trochanter, perpendicular to the femoral longitudinal axis (Fig. 1).[6] The cross-over sign is a measure helpful in estimating the acetabular retroversion.[12] After the acetabular edges are drawn on the roentgenogram, if the anterior acetabular edge is more medial than the posterior edge, it is designated as negative and if it is more lateral or cross-over, then it is designated as positive (Fig. 2).[7] The posterior wall sign is described as the anterior acetabular edge being more laterally placed than the femoral head (Fig. 3).[8]

We measured the abovementioned hip parameters and performed power analysis if the patient number was sufficient for an adequate sample size.

Results

Measurements of the male patients showed the following; the mean articulo-trochanteric distance was 19.54 ± 4.25 mm for the right hip (ATD-R) and 19.23 ± 4.10 mm for the left hip (ATD-L), the CE angle of the right hip (CEA-R) was 36.65°±6.90° and of the left hip (CEA-L) was 36.16°±6.44°, the acetabular index of the right hip (AI-R) was 36.46°±5.20° and of the left hip (AI-L) was 36.84°±4.66°, and the collodiaphyseal angle of the right hip (CDA-R) was 139.54°±8.77° and of the left hip (CDA-L) was 138.42°±7.35°. The right hip cross-over sign (COS-R) was positive in 89 cases (7.56%) and negative in 1089 (92.44%). The left hip cross-over sign (COS-L) was positive in 91 cases (7.72%) and negative in 1087 (92.28%). The right hip posterior wall sign (PWS-R) was positive in 53 cases (4.49%) and negative in 1125 (95.51%). The left hip posterior wall sign (PWS-L) was positive in 50 cases (4.24%) and negative in 1128 (95.76%).

Measurements of the female patients showed the following; the mean ATD-R was 18.90 ± 4.1 mm and the ATD-L was 18.93 ± 3.94 mm, the CEA-R was 32.83°±7.54° and the CEA-L was 34.21°±7.06°, the AI-R was 39.23°±5.02° and the AI-L was 39.22°±4.70°, and the CDA-R was 138.01°±7.44° and the CDA-L was 137.06°±7.55°. The COS-R was positive in 39 cases (4.86%) and negative in 763 (95.14%). The COS-L was positive in 41 cases (5.11%) and negative in 761 (94.89%). The PWS-R was positive in 31 cases (3.86%) and negative in 771 (96.14%). The PWS-L was positive in 33 cases (4.11%) and negative in 769 (95.89%).

When the patients were evaluated together as a single population, the ATD-R was 19.67 ± 4.52 mm and the ATD-L was 19.10 ± 4.58 mm. The CEA-R was measured 35.11°±7.41° and the CEA-L was measured 35.37°±6.76°. The AI-R was 37.58°±5.30° and the AI-L was 37.80°±4.82°. The CDA-R was 138.60°±8.27° and the CDA-L was 137.84°±8.01°. The COS-R was positive in 128 cases (6.46%) and negative in 1852 (93.54%). The COS-L was positive in 132 cases (6.67%) and negative in 1848 (93.33%). The PWS-R was positive in 84 cases (4.24%) and negative in 1896 (95.76%). The PWS-L was positive in 83 cases (4.19%) and negative in 1897 (95.81%) (Table 1).

Statistical analysis

In the statistical power analysis of the 1980 patients, the effect value of the right and left hip ATD, CEA, AI and CDA was 0.99. According to this result, the number of patients chosen for this study is adequate and the study possesses a high effect size power.

In the evaluation of the findings, statistical analysis was done at 99% confidence level. In the whole patient population, the power analysis revealed that, in comparison of the ATD-R and ATD-L, the α value was 0.01 and the power (1-β) of the study was 1. Again, in comparison of the CEA-R and CEA-L, the α value was 0.01 and the power (1-β) of the study was 0.78. Comparison of the AI-R and AI-L demonstrated the α value as 0.01 and the power (1-β) of the study as 0.76. When the CDA-R and CDA-L were compared with power analysis, the α value was 0.01 and the power (1-β) of the study was 0.98.

In the whole patient population and according to the independent samples t-test, significant differences between the ATD-R and ATD-L ($p = 0.003$) and CEA-R and CEA-L ($p < 0.001$) and insignificant differences between the AI-R and AI-L ($p = 0.192$) and CDA-R and CDA-L ($p < 0.001$) of the two groups were detected. Again in the whole population and based on the chi-square test, no significant difference between the COS-R and COS-L ($p = 0.797$) and PWS-R and PWS-L ($p = 0.937$) of the two groups was found. According to these results, when the whole of the population is considered, there was a statistically significant difference between ATD-R and ATD-L and CEA-R and CEA-L, while there were no statistically significant differences for the AI, CDA, COS and PWS.

Evaluation of the genders with the independent samples t-test showed the following results. There was a significant difference between males and females between the two groups in terms of ATD-R ($p < 0.001$), CEA-R ($p < 0.001$), CEA-L ($p < 0.001$), AI-R ($p < 0.001$), AI-L ($p < 0.001$), CDA-R ($p = 0.009$) and CDA-L ($p < 0.001$). However, there were no significant differences between males and females in terms of ATD-L between the two groups ($p = 0.170$). Comparison of the genders with the chi-square test revealed no significant relationships between males and females in terms of COS-R and COS-L between the two groups ($p = 0.017$ and $p = 0.022$, respectively). Again, no significant relationship between males and females was found in terms of PWS-R and PWS-L between the groups ($p = 0.492$ and 0.888, respectively). According to these results, there are statistically significant differences between males and females between the right hip and left hip for all measurements except for ATD-L. The presence of this difference between males and females is statistically an expected result.

When the CEAs of all hip population was studied with the independent samples t-test, a significant difference between the 18–29 age interval and 30–39, 40–49, 50–59 and 60–65 age intervals was detected ($p < 0.001$). Similarly, the study of age intervals with the independent samples t-test revealed a significant

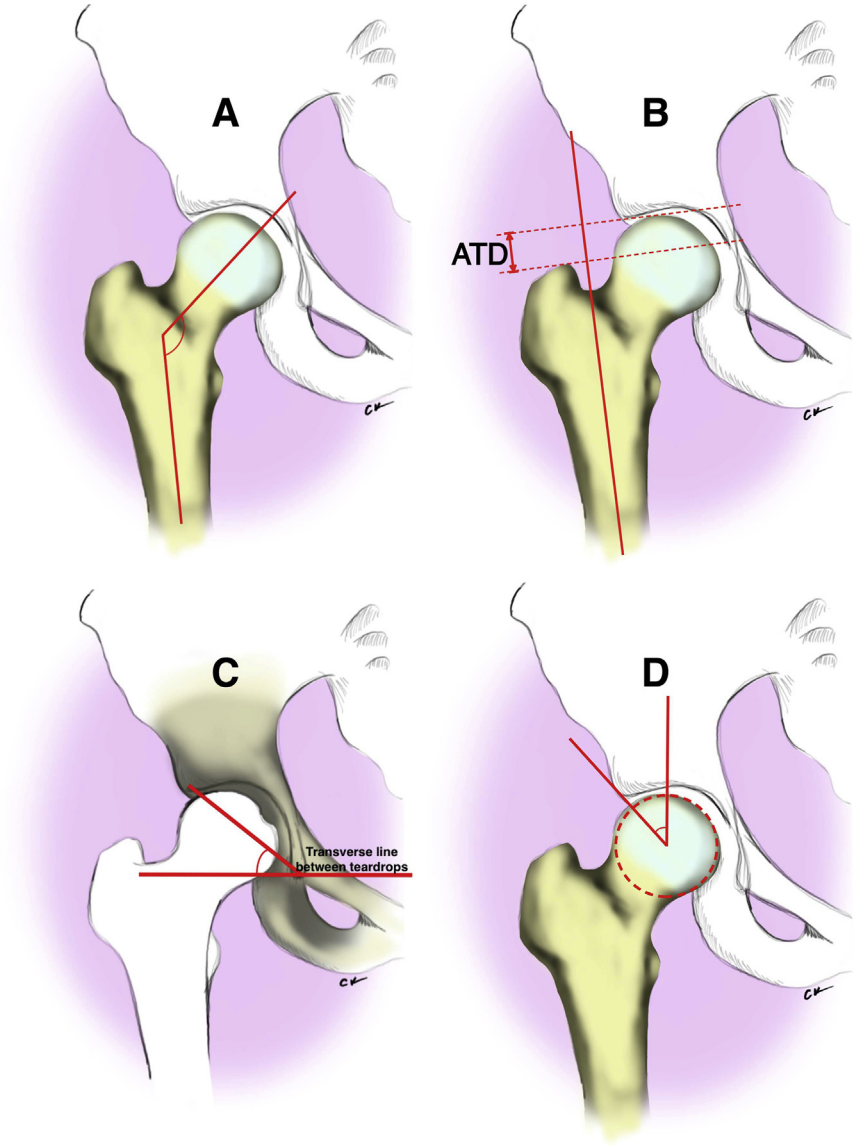

Fig. 1. (**A**) Visual presentation of the collodiaphyseal angle, (**B**) articulo-trochanteric distance, (**C**) acetabular index, and (**D**) CE angle.

difference between the 30–39 age interval and 50–59, 60–65 age intervals ($p < 0.001$). However, no significant difference was observed between the 30–39 age interval and 40–49 age interval ($p = 0.02$). A significant difference between the 40–49 age interval and 50–59, 60–65 age intervals was present ($p < 0.001$). The difference between the 50–59 age interval and 60–65 age interval was again a significant one ($p < 0.001$) (Table 2).

Discussion

Among the CE angle, acetabular index, collodiaphyseal angle, articulo-trochanteric distance, cross over sign, and posterior wall sign, the parameter that should be used most frequently in orthopedic surgery is the collodiaphyseal angle. The CDA (also known as the Mikulicz angle) is between 120 and 145° (mean: 135°).[13] Different mean CDA values were reported for different populations. This angle is 125–126° in the English population,[14] 125° in the Finnish population,[15] and 129–132° in the Malaysian population.[16] The CDA was between 137 and 139° in our study. The CDA has a critical importance in proximal femoral nail (PFN), dynamic hip screw (DHS) and dynamic condylar screw (DCS) applications and is sent with a 135° collodiaphyseal angle. Although we take measurements of the intact hip before surgical interventions on hip fractures, production of implants with a CDA of 138° may be more appropriate for Turkish patients. We believe that the CDA values determined in this study will illuminate the path for proximal femoral plate fixation and femoral prosthesis stems.

Many orthopedic surgeons from Turkey report lack of biometric concordance of intraoperative implants and patients in orthopedic surgery, and these implants are mostly produced by the European or American medical companies. Companies producing medical implants use their national measurement parameters in the production of these implants. There are various case reports of implants reporting the inappropriateness for the patient's femoral anatomy.[17,18] On the other hand, when using relatively larger femoral implants, parameters such as the neck distance and collodiaphyseal distance need to be changed.[19,20] When the implant is not found suitable for the bone biometry during surgical intervention, frequently, unnecessary bone resection is necessary. Publications such as this one on local populations are fundamental in the production of implants with more suitable length and anatomy.

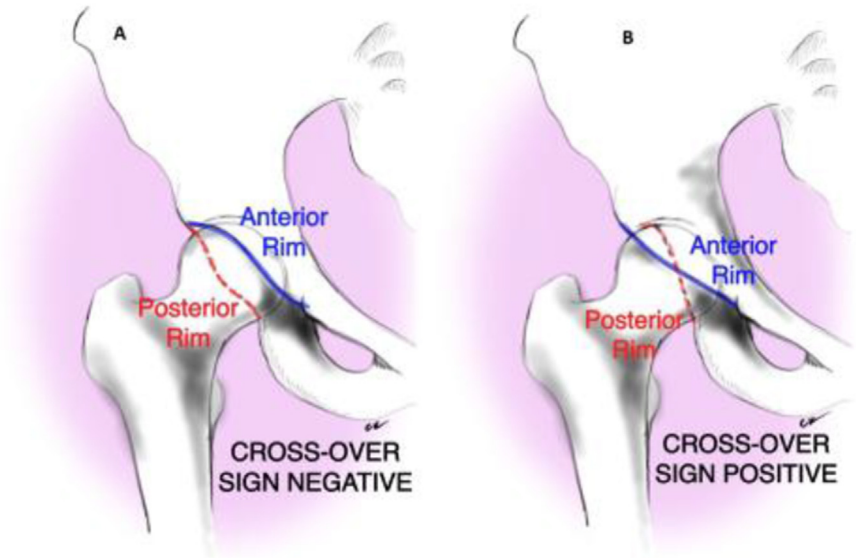

Fig. 2. (**A**) Negative and (**B**) positive cross-over sign.

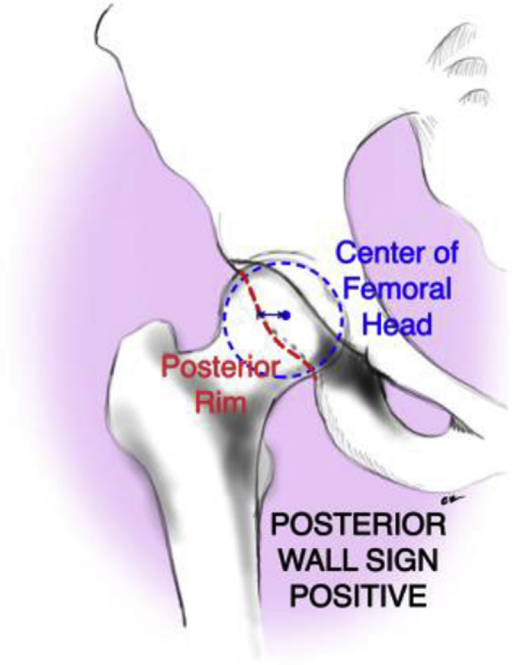

Fig. 3. Positive posterior wall sign.

Ozçelik et al. have found the mean CE angle as 32.5° in a Turkish population of 1316 cases aged between 5 and 75 years in their evaluation of anteroposterior pelvic roentgenograms.[21] In the present study, we found the mean CEA-R as 35.11° and the mean CEA-L 35.37°. But while we examined participants aged between 18 and 65 years, Ozçelik et al. examined cases aged 5 years and over 65 years. When we evaluated the male and female participants, there was a 0.5°–1.5° difference between the right and left hips, which is statistically significant. Wynne-Davies reported that this difference may be due to differences in their loads.[22] In the present study, when the age groups were classified and compared in decades, there were significant differences between all the decades except among the 30–39 age interval and 40–49 age interval which showed that there was no statistically significant difference between these two age groups. However, Ozçelik et al.[21] found that there was a significant correlation between the CEA and age. In addition, the authors formulated the following relationship between age and CE angle: $CE^{angle} = 27.38 + 0.15^{*}$ (age).[21]

There are two studies in the literature which examine the AI of adults in the Turkish population. The most comprehensive one is the study by Akel et al. conducted on 2788 children aged between 6 months and 8 years.[23] In another study, the AI of 1162 patients from Eskişehir region (aged between 5 and 75 years) were measured and was found to be 39.2°±4.6°.[24] In the present study, we found a mean of 37.58°±5.30° in the right hip and 37.80°±4.82° in the left hip. Our values and the values found by Ozçelik et al. are different from studies conducted in other countries. This difference may be due to differences in patient age groups, gender, race or region.

In the present study, the COS and PWS were also measured while evaluating the pelvic AP roentgenograms. The findings of COS were shown to be helpful in estimating the acetabular retroversion.[12,25] Approximately 6.5% of the healthy population had acetabular retroversion in our study. Among these, approximately 4.2% had positive PWS. Acetabular retroversion is significantly higher among males.

Our study had some limitations. Numerically, a higher number of hip roentgenograms could be measured but when the power analysis was done to yield certain results, we believe we had reached a high effect power (0.99) and an adequate sample size. Another limitation may be the measurement of hip roentgenograms from nine different cities. While nine regions may not accurately represent all mosaicism of Turkey, we unfortunately did not have the means to order hip roentgenograms from all cities. Another limitation was our roentgenography technique. While radiology technicians in our hospital and in other cities were briefed on the roentgenogram, the position of the patient and personal factors (i.e. technician and patient) at the time of examination might have caused errors in measurement.

In conclusion, the cross-over sign and posterior wall sign values along with the articulo-trochanteric distance, CE angle, collodiaphyseal angle, and acetabular index values of 3960 hips in 1980 patients from a healthy Turkish population aged between 18 and 65

Table 1
Hip parameters according to gender.

Parameter	Male (n = 1178)	Female (n = 802)	Total (n = 1980)
Right hip articulo-trochanteric distance (mm)	19.54 ± 4.25	18.90 ± 4.1	19.67 ± 4.52
Left hip articulo-trochanteric distance (mm)	19.23 ± 4.10	18.93 ± 3.94	19.10 ± 4.58
Right hip CE angle (°)	36.65 ± 6.90	32.83 ± 7.54	35.11 ± 7.41
Left hip CE angle (°)	36.16 ± 6.44	34.21 ± 7.06	35.37 ± 6.76
Right hip acetabular index (°)	36.46 ± 5.20	39.23 ± 5.02	37.58 ± 5.30
Left hip acetabular index (°)	36.84 ± 4.66	39.22 ± 4.70	37.80 ± 4.82
Right hip collodiaphyseal angle (°)	139.54 ± 8.77	138.01 ± 7.44	138.60 ± 8.27
Left hip collodiaphyseal angle (°)	138.42 ± 7.35	137.06 ± 7.55	137.84 ± 8.01
Right hip cross-over sign			
Positive	89+(7.56%)	39+(4.86%)	128+(6.46%)
Negative	1089−(92.44%)	763−(95.14%)	1852−(93.54%)
Left hip cross-over sign			
Positive	91+(7.72%)	41+(5.11%)	132+(6.67%)
Negative	1087−(92.28%)	761−(94.89%)	1848−(93.33%)
Right hip posterior wall sign			
Positive	53+(4.49%)	31+(3.86%)	84+(4.24%)
Negative	1125−(95.51%)	771−(96.14%)	1896−(95.76%)
Left hip posterior wall sign			
Positive	50+(4.24%)	33+(4.11%)	83+(4.19%)
Negative	1128−(95.76%)	769−(95.89%)	1897−(95.81%)

COS: Cross over sign; PWS: Posterior wall sign.

Table 2
Variation of the CE angle by age groups.

Age	Number of patients	Mean CE angle
18–29	447	33.2 ± 5.7
30–39	537	35.1 ± 5.8
40–49	534	35.4 ± 7.1
50–59	297	36.9 ± 6.9
60–65	165	37.7 ± 6.4
Total	1980	35.24 ± 7.56

years were determined in this study. Thus, we hope to have shed light for future studies and implants to be produced for the Turkish population.

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