ORIGINAL ARTICLE

UDC: 616-055.1/.3-071.3::611.96
DOI: 10.2298/VSP1111935J

Sex differences in anatomical parameters of acetabulum among asymptomatic Serbian population

Polne razlike u anatomskim parametrima acetabuluma kod asimptomatske srpske populacije

Dejan Jeremić, Ivana Živanović Mačužić, Maja Vulović

Medical Faculty, University of Kragujevac, Department of Anatomy and Forensic Medicine, **Kragujevac, Srbija**

Abstract

Background/Aim. Anatomical parameters of the bony components of the hip joint are essential for better understanding of etiopathogenesis of diseases like primary osteoarthrosis of the hip joint. The aim of this reserch was to examine the normal acetabular morphometry in Serbian population and to determine whether there are sex differences in anatomical parameters of the acetabulum among asymptomatic subjects. **Methods.** Pelvic radiographics of 320 adult asymptomatic patients (640 hips) were analyzed in 170 men and 150 women to determine the morphology of the acetabulum in Serbian population. For each hip the center edge angle of Wiberg (CEA), the acetabular angle of Sharp (AA), acetabular depth (AD), acetabular roof obliquity (ARO) and roof angle (RA) were measured. **Results.** The following average measurements for acetabulum geometry were obtained ($\bar{x} \pm SD$): CEA – 33.5 ± 6.5° (33.6 ± 5.8° in male, 33.3 ± 6.9° in female), AA – 38.0 ± 3.8° (37.5 ± 3.6° in male, 38.5 ± 3.9° in female), AD – 11.9 ± 2.8 mm (12.5 ± 2.7 mm in male, 11.2 ± 2.7 mm in female), ARO – 7.6 ± 5.7° (6.2 ± 4.9° in male, 9.0 ± 6.0° in female) and RA – 18.4 ± 10.0° (19.6 ± 8.5° in male, 17.1 ± 9.5° in female). There were significant differences in the CEA, AA, AD, ARO and RA related to gender ($p < 0.01$, *t*-test). **Conclusion.** There are significant gender differences in Serbian population for all the examined anatomical parameters of acetabulum. We found sex-related differences in acetabular morphology, female acetabulum being marginally more dysplastic than male acetabulum. There is also a clear tendency of female hips to be more dysplastic than male ones.

Key words:
hip joint; acetabulum; anatomy; gender identity; serbia.

Apstrakt

Uvod/Cilj. Anatomski parametri koštanih struktura zgloba kuka najvažniji su za bolje razumevanje etiopatogeneze bolesti kao što je primarna osteoartroza zgloba kuka. Cilj istraživanja bio je ispitivanje normalne acetabularne morfometrije i postojanje polnih razlika u anatomskim parametrima acetabuluma, kod asimptomatskih osoba srpske populacije. **Metode.** Analizirani su radiografski snimci karlice 320 odraslih asimptomatskih ispitanika (640 zglobova kuka) srpske populacije radi utvrđivanja normalne morfologije acetabuluma. Među ispitanicima bilo je 170 muškaraca i 150 žena. Za svaki zglob kuka mereni su Wiberg ugao (CEA), Šarp ugao (AA), acetabularna dubina (AD), kosina krova acetabuluma (ARO) i ugao krova acetabuluma (RA). **Rezultati.** Dobijene su sledeće vrednosti acetabularne morfometrije ($\bar{x} \pm SD$): CEA je 33,5 ± 6,5° (33,6 ± 5,8° kod muškaraca, 33,3 ± 6,9° kod žena), AA – 38,0 ± 3,8° (37,5 ± 3,6° kod muškaraca, 38,5 ± 3,9° kod žena), AD – 11,9 ± 2,8 mm (12,5 ± 2,7 mm kod muškaraca, 11,2 ± 2,7 mm kod žena), ARO – 7,6 ± 5,7° (6,2 ± 4,9° kod muškaraca, 9,0 ± 6,0° kod žena) i RA – 18,4 ± 10,0° (19,6 ± 8,5° kod muškaraca, 17,1 ± 9,5° kod žena). Uočene su statistički značajne razlike u odnosu na pol za sve ispitivane parametre: CEA, AA, AD, ARO i RA ($p < 0,01$, *t* test). **Zaključak.** Za sve ispitivane anatomske parametre acetabuluma postoje statistički značajne razlike u odnosu na pol, pri čemu je ženski acetabulum pokazivao veće znake displazije nego acetabulum muškaraca. Dobijeni rezultati u skladu su sa istraživanjima razlika displastičnosti muškog i ženskog acetabuluma, vršenih u različitim rasnim grupama.

Ključne reči:
kuk, zglob; acetabulum; anatomija; pol; srbija.

Correspondence to: Dejan Jeremić, Medical Faculty, University of Kragujevac, Department of Anatomy and Forensic Medicine, Svetozara Markovića 69, 34 000 Kragujevac, Serbia. Phone: +381 64 261 44 27. E-mail: dejananatom@yahoo.com

Introduction

The hip joint is functionally a three-dimensional ball and socket joint, often called cotyloid joint because of its anatomical feature. It enables movements in all the three planes as rotation. The femoral head articulates with the cup-shaped (cotyloid) acetabulum, its center lying a little below the middle third of the inguinal ligament. The acetabulum, with a median curvature radius of 2.7 cm, is formed by parts of the *ilium*, *pubis*, and *ischium* which rejoin in a cartilaginous Y to the hip bone. The femoral head, slightly more than one-half a sphere, has a constant curvature radius of about 2.5 cm. Its smoothness is interrupted *posterior inferior* to its center by a small rough *fovea*. The femoral neck is about 5 cm long and connects the head to the shaft at the angle of about 125° [1].

More information is needed about the anatomical parameters of the acetabulum of the normal hip joint, including its shape, depth at precise locations, and the influence of age, sex and congenital morphology [2, 3]. As race, climate, heredity and geographical areas have strong influence on the anthropometric parameters of the bone, therefore, the present study was undertaken to note the average anatomical parameters of the acetabular part of the hip joint in Serbian population. Anatomical parameters of the bony components of the hip joint are essential for better understanding of etiopathogenesis of diseases like primary osteoarthrosis of the hip joint. Also, knowledge about various bony components of the hip joint will not only help the radiologists, but will be also of immense importance to the orthopedicians and prosthetists to construct suitable prosthesis. The awareness about average dimensions of hip bones joints in both sexes will also help in early detection of disputed sex by forensic experts.

The aim of this study was to examine normal acetabular morphometry and to determine whether there are sex differences in anatomical parameters of acetabulum among asymptomatic subjects without structural change.

Methods

Pelvic radiographies of 320 adult patients, 170 men and 150 women, with clinically normal hip joints (640 hips) were analyzed in to determine the morphology of the acetabulum in Serbian population. The average age of patients was 47.8 years (from 21 to 65), divided by decades: the twenties 10.0% (32), the thirties 15.0% (48), the forties 19.69% (63), the fifties 28.12% (90) and over sixties 27.19% (87). The research was conducted as a prospective study. For each acetabulum the center-edge angle of Wiberg (CEA), the acetabular angle of Sharp (AA), acetabular depth (AD), acetabular roof obliquity (ARO) and roof angle (RA) were measured (Figure 1).

Patients with known hip disease or pain located in the hip region, including ambiguous pain probably of lumbar origin but irradiating to the region of the greater trochanter, groin, or thigh, were excluded from this study. We also excluded patients with bone disorders such as Paget's disease, femoral head disease, acquired deformities, unequivocal OA of the hip, and evident osteophytes or cysts adjacent to the hip joint cavity. Films with incorrect patient positioning (misalignment of the sacropubic symphysis vertical axis ≥ 1.5 cm) were also excluded.

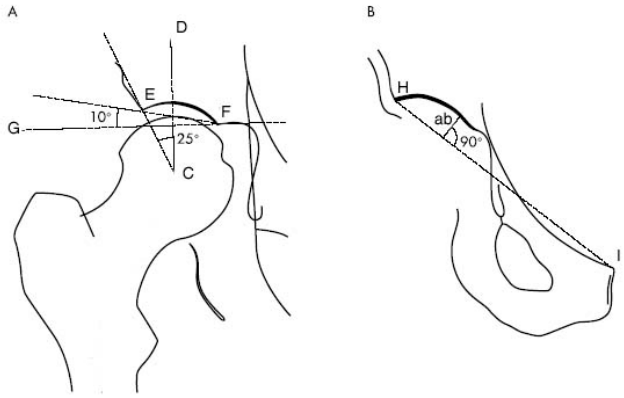

Fig. 1 A – DCE (the center-edge angle of Wiberg); GFE – acetabular roof obliquity; B – acetabular depth (segment "ab")

Antero-posterior (AP) radiograph was used to measure the radiography of the hip joint. The patients were placed in the supine position with legs extended and internally rotated for 15°, with a distance of 100 cm between the radiographic source and the film. The central radiographic ray was aligned to be perpendicular to the cassette, entering 5 cm superior to the pubic symphysis. All measurements were made using a new Plexiglas instrument, the „arthrometer", which comprises a ruler and protactor appropriate for measuring hip architectural angles [3]. Interpretations were performed by a single physiatrist trained in the radiographic characteristics of acetabular morphometry.

The AA was measured from the intersection of the horizontal line passing through the bottom of the "tear drop" and the line connecting the bottom of the "tear drop" to the lateral lip of the acetabulum. The greater the angle, the more dysplastic the hip (Figure 1A) [4, 5].

The CEA was defined as the angle between the line joining the center of the femoral head to the lateral margin of the acetabular roof and the line perpendicular to that joining the centers of the two femoral heads (Figure 1B) [6]. The center of each femoral head was established by superimposing a circle around its margin.

The AD was defined as the greatest perpendicular distance from the acetabular roof to the line joining the lateral margin of the acetabular roof and the upper corner of the symphysis pubis on the same side (Figure 1B) [6].

The ARO was defined as the angle between the line connecting the lateral edge of the acetabular roof and the lower iliacus tip of the acetabular surface and the line parallel to the pelvic "tear drop" (Figure 1A) [5].

The RA was determined by the line along the lateral side of the *ilium* on the acetabular surface and the line parallel to the pelvic "tear drop" [5].

Sex-related differences of anatomical parameters of acetabulum were assessed by paired samples *t*-test. A significant level of $p < 0.05$ was assumed. Statistical software for Windows version 15.0 SPSS was used for all calculations.

Results

Table 1 summarizes the means and standard deviations of the center-edge angle of Wiberg, acetabular angle of Sharp, acetabular depth, acetabular roof obliquity and roof angle of groups in Serbian population.

The average CEA was significantly greater in the men than in the women: 33.6° (SD = 5.8°) in male hips and 31.3° (SD = 6.9°) in female hips ($p < 0.01$, *t*-test).

The average AA was significantly lower in the men than in the women: 37.5° (SD = 3.6°) in male hips and 38.5° (SD = 3.9) in female hips ($p < 0.01$, *t*-test).

The average AD was significantly greater in the men than in the women: 12.5 mm (SD 2.7) in male hips and 11.2 mm (SD = 2.7) in female hips ($p < 0.01$, *t*-test).

Table 1

Values of each parameter of acetabulum by gender of subjects in Serbian population

Acetabular parameters	Male	Female	*t*-test	*p*	Total
CEA (°)	33.6 ± 5.8	31.3 ± 6.9	0.51	< 0.01*	32.5 ± 6.4
AA (°)	37.5 ± 3.6	38.5 ± 3.9	0.28	< 0.01*	38.0 ± 3.8
AD (mm)	12.5 ± 2.7	11.2 ± 2.7	0.35	< 0.01*	11.9 ± 2.8
ARO (°)	6.2 ± 4.9	9.0 ± 6.0	1.57	< 0.01*	7.6 ± 5.7
RA (°)	19.6 ± 8.5	17.1 ± 9.5	1.02	< 0.01*	18.4 ± 10.0

***significant difference**
CEA – Wiberg angle; AA – acetabular angle of Sharp; AD – acetabular depth; ARO – acetabular roof obliquity; RA – roof angle

The following parameters for acetabular geometry were obtained ($\bar{x}$ ± SD): CEA – 32.5 ± 6.4° (33.6 ± 5.8° in male, 31.3 ± 6.9° in female), ($\bar{x}$ ± SD) AA – 38.0 ± 3.8° (37.5 ± 3.6° in male, 38.5 ± 3.9° in female) AD – 11.9 ± 2.8 mm (12.5 ± 2.7 mm in male, 11.2 ± 2.7 mm in female), ARO – 7.6 ± 5.7° (6.2 ± 4.9° in male, 9.0 ± 6.0° in female) and 18.4 ± 9.1° (19.6 ± 8.5° in male, 17.1 ± 9.5° in female).

Acetabular angle, center – edge angle of Wiberg, acetabular depth, acetabular roof obliquity and roof angle differed significantly by gender.

The average ARO was significantly lower in the men than in the women: 6.2° (SD = 4.9) in male hips and 9.0° (SD = 6.0) in female hips ($p < 0.01$, *t*-test).

The Average RA was significantly greater in the men than in the women: 19.6° (SD = 8.5) in male hips and 17.1° (SD = 9.5) in female hips ($p < 0.01$, *t*-test).

Distribution of anatomical parameters of acetabulum and sex related differences within various ethnic groups are presented in Tables 1–6 [7–15].

Table 2

The published values of the mean center-edge angle of Wiberg (°) by gender and ethnic group [7–15]

The ethnic group	Mean centre edge angle of Wiberg (°)		*p*	Total
	Male	Female		
Turkish	34.5 ± 7.4	35.0 ± 7.0	> 0.05	34.6 ± 7.2
British	31.7 ± 5.5	30.4 ± 5.4	< 0.1	31.1 ± 5.7
Denmark	35.0 ± 7.3	35.0 ± 7.4	> 0.05	35.0 ± 7.4
Japanese	29.5 ± 5.9	27.9 ± 6.5	< 0.001*	28.7 ± 6.2
Singaporean	30.6 ± 8.1	33.5 ± 7.1	< 0.05*	31.2 ± 7.9
Korean	32.6 ± 5.7	32.3 ± 6.8	> 0.05	32.5 ± 6.4
Malawian	34.0 ± 7.5	34.3 ± 7.5	> 0.5	34.2 ± 7.5

*** significant difference**

Table 3

The published values of the acetabular angle of Sharp (°) by gender and ethnic group [7–15]

The ethnic group	Acetabular angle of Sharp (°)		*p*	Total
	Male	Female		
Denmark	37.0 ± 3.5	39.1 ± 3.7	< 0.05*	38.0 ± 3.6
British	36.2 ± 2.8	39.0 ± 3.2	< 0.001*	37.6 ± 3.0
Japanese	39.0 ± 3.2	41.8 ± 3.4	< 0.001*	40.4 ± 3.3
Singaporean	39.9 ± 6.0	38.3 ± 5.9	> 0.05	39.1 ± 6.0
Korean	36.5 ± 3.5	37.5 ± 3.8	< 0.01*	37.0 ± 3.7
Malawian	36.9 ± 4.0	38.6 ± 4.9	< 0.05*	37.6 ± 4.5

*** significant difference**

Table 4

The published values of the acetabular depth (mm) by gender and ethnic group [9, 11, 18]

Ethnic group	Acetabular depth (mm)		*p*	Total
	Male	Female		
Turkish	13.8 ± 3.6	13.3 ± 3.0	> 0.05	13.6 ± 3.3
Austrian	17.9 ± 1.2	14.5 ± 2.2	< 0.05*	16.2 ± 1.7
Korean	11.5 ± 2.6	10.2 ± 2.6	< 0.01*	10.9 ± 2.7

*** significant difference**

Table 5

The published values of the acetabular roof obliquity (°) by gender and ethnic group [11 12]

Ethnic group	Acetabular roof obliquity (°)		*p*	Total
	Male	Female		
Japanese	4.6 ± 4.1	5.4 ± 4.5	< 0.05*	5.0 ± 4.3
Korean	5.2 ± 4.8	8.0 ± 5.9	< 0.01*	6.6 ± 5.6
Singaporean	7.8 ± 6.5	7.8 ± 6.8	> 0.05	7.8 ± 6.7

*** significant difference**

Table 6

The published values of the acetabular roof angle (°) by gender and ethnic group [11]

Ethnic group	Roof angle (°)		*p*	Total
	Male	Female		
Japanese	20.9 ± 10.1	17.9 ± 10.2	< 0.01*	19.4 ± 10.2
Korean	18.6 ± 8.4	16.1 ± 9.4	< 0.01*	17.4 ± 9.0

*** significant difference**

Discussion

According to the obtained results it can be concluded that Serbian female acetabul in our study population are more dysplastic than in males using all methods of measurement. Regarding gender differences in the five most important acetabular parameters, CEA, AA, AD, ARO, RA, we found a distinct discrepancy between our data and those reported in the literature [7–15].

The center-edge angle, originally described by Wiberg [16], is perhaps the most used indicator and it is included in most of the radiographic classifications. It evaluates the degree of lateral coverage of the femoral head in the frontal plane and a large CEA correlates with a deep acetabulum. Consensus seems to exist regarding the normal and pathological values of the classic CEA. A classic CEA of more than 20° between 3 and 17 years and a classic CEA of more than 25° in adults was considered "normal", and CEA below 20° in adults and below 15° in children and adolescents "pathological" [16]. Hips with CEA between 20° and 25° in adults and between 15° and 20° in children and adolescents are "intermediate" or "uncertain" hips. However, detailed studies are required to evaluate the normal and pathological values of the refined CEA. Serbian male CEA (33.6 ± 5.8°) is significantly higher ($p < 0.05$) than female CEA (31.3 ± 6.9°), corresponding to the findings of Lavy [13] in Japanese hips, who found a significantly higher male (29.5 ± 5.9°) than female CEA value (27.9 ± 6.5°). Umer et al. [12] reported the mean CEA in Singaporean population was 31.2 ± 7.9° (range 5–52°) and mean female CEA (33.5 ± 7.1°) that of is significantly higher ($p < 0.05$) than male CEA (30.6 ± 8.1°). No significant differences were found in the CEA in Malawian, British, Korean, Turkish and Denmark population related to gender [7, 9–11, 13–15]. The CEA differed significantly by gender in Japanese and Singaporean population.

The acetabular angle of Sharp is one of the most common anatomical parameters of acetabulum used to assess acetabular dysplasia. Our measurements revealed the Serbian male AA value (37.5 ± 3.6°) was lower than the female one (38.5 ± 3.9°, $p < 0.05$) corresponding to the findings of Jacobsen in the Denmark population, who found a significantly higher female value (39.1 ± 3.7°) than male AA value (37.0 ± 3.5°) in the right hip. These results differ from those reported by Umer et al. [12], who observed a male AA of 39.9 ± 6.0° and a female AA of 38.3 ± 5.9° in Singaporean population. No significant differences were found in the AA in Singaporean population related to gender. The AA differed significantly by gender in Malawian, British, Japanese, Korean and Denmark population [7, 8, 10, 11, 13, 14].

The acetabular index of depth to width evaluates the depth of the acetabulum. In comparison between normal and dysplastic hips with osteoarthritis, all normal hips were shown to have acetabular index values over 38°. Murrey [17] reported another method, which use acetabular depth to compensate for the inaccuracy of the Wiberg angle which was caused by formation of a bony spur of lateral margin of the acetabulum and displacement of the femoral head. It is considered as acetabular dysplasia if the acetabular depth is less than 9 mm. Regarding the AD we determined a significantly lower value of the Serbian female (11.2 ± 2.7°) than the male (12.5 ± 2.7°, $p < 0.05$). This agrees with the findings of Genser-Strobl et al. [18], who also found a significantly higher male value (17.98 ± 1.22°) than female (14.50 ± 2.21°)

($p < 0.05$) in Austrian population. No significant differences were found in the AD in Turkish population related to gender [9, 19]. The AD differed significantly by gender in Austrian and Korean population [11, 18].

Acetabular roof obliquity is used to evaluate the orientation of the acetabular roof in a coronal plane, and the superior lateral coverage of the femoral head. Normal values are 10° and under, values above 10° are frequently found in acetabular dysplasia [5]. Acetabular roof obliquity was normal if the angle was less than 30° under one year of age, if the angle was less than 25° between age 1 and 3, and if the angle was less than 20° from age 3 to adult [20]. The mean ARO 7.6 ± 5.7° (both genders) did not differ from the value given by Han et al. [11]. Furthermore, Serbian female ARO (9.0 ± 6.0°) differed significantly from the male value (6.2 ± 4.9°, $p < 0.01$). These values concur with the findings of Umer et al. [12] who reported a similar difference between female (7.78 ± 6.81°) and male (7.79 ± 6.46°) in Singaporean population. The ARO differed significantly by gender in Japanese and Korean population [7, 8, 11].

Our male RA (19.6 ± 8.5°) is significantly higher ($p < 0.01$) than our female RA (17.1 ± 9.5°), corresponding to the findings of Nakamura et al. [21] who found a significantly higher male (20.9 ± 10.1°) than female RA value (17.9 ± 10.2°). The RA differed significantly by gender in Japanese and Korean population [7, 8, 11].

Conclusion

There are significant gender differences for all the examined anatomical parameters of the acetabulum in Serbian population. There is also a clear tendency of female hips within the ethnic group to be more dysplastic than their male counterparts. We also found sex-related differences in acetabular morphology which were the cause for more dysplastic female acetabula compared with male.

R E F E R E N C E S

1. *Mall G, Graw M, Gehring K, Hubig M.* Determination of sex from femora. Forensic Sci Int 2000; 113(1–3): 315–21.
2. *Lanyon P, Muir K, Doherty S, Doherty M.* Age and sex differences in hip joint space among asymptomatic subjects without structural change: implications for epidemiologic studies. Arthritis Rheum 2003; 48(4): 1041–6.
3. *Lequesne M, Morvan G.* Description of the potential of an arthrometer for standard and reduced radiographs suitable to measurement of angles and segments of hip, knee, foot and joint space widths. Joint Bone Spine 2002; 69(3): 282–92.
4. *Cooperman DR, Wallensten R, Stulberg SD.* Acetabular dysplasia in the adult. Clin Orthop Relat Res 1983; 175: 79–85.
5. *Delaunay S, Dussault RG, Kaplan PA, Alford BA.* Radiographis measurements of dysplastic adult hips. Skeletal Radiol 1997; 26(2): 75–81.
6. *Antoniades L, Spector TD, Macgregor AJ.* The genetic contribution to hip joint morphometry and relationship to hip cartilage thickness. Osteoarthritis Cartilage 2001; 9(6): 593–5.
7. *Fuji G, Funayama K, Benson M.* Radiological measurement of the hip joint: comparison between Japanese and British. British and Japanese Orthopaedic Associations Combined Congress; 2000 Oct 3–6; London; 2000.
8. *Inoue K, Wicart P, Kawasaki T, Huang J, Ushiyama T, Hukuda S*, et al.. Prevalence of hip osteoarthritis and acetabular dysplasia in French and Japanese adults. Rheumatology 2000; 39(7): 745–8.
9. *Goker B, Sancak A, Haznedaroglu S.* Radiographic hip osteoarthritis and acetabular dysplasia in Turkish men and women. Rheumatol Int 2005; 25(6): 419–22.
10. *Jacobsen S, Sonne-Holm S, Søballe K, Gebuhr P, Lund B.* Hip dysplasia and osteoarthrosis: a survey of 4151 subjects from the Osteoarthrosis Substudy of the Copenhagen City Heart Study. Acta Orthop 2005; 76(2): 149–58.
11. *Han CD, Yoo JH, Lee WS, Choe WS.* Radiographic parameters of acetabular dysplasia in Korean adults. Yonsei Med J 1998; 39(5): 404–8.
12. *Umer M, Thambyah A, Tan WTJ, Das De S.* Acetabular morphometry for determining hip dysplasia in the Singaporean population. J Orthop Surg 2006; 14(1): 27–31.
13. *Lavy CB, Msamati BC, Igbigbi PS.* Racial and gender variations in adult hip morphology. Int Orthop 2003; 27(6): 331–3.
14. *Msamati BC, Igbigbi PS, Lavy CB.* Geometric measurements of the acetabulum in adult Malawians: radiographic study. East Afr Med J 2003; 80(10): 546–9.
15. *Jacobsen S, Sonne-Holm S.* Hip dysplasia: a significant risk factor for the development of hip osteoarthritis. A cross-sectional survey. Rheumatology (Oxford) 2005; 44(2): 211–8.
16. *Wiberg G.* Studies on dysplastic acetabulae and congenital subluxation of the hip joint. Acta Orthop Scand (Suppl) 1939; 58: 1–132.
17. *Murrey RO.* The etiology of primary osteoarthritis of the hip. Br J Radiol 1965; 38(455): 810–24.
18. *Genser-Strobl B, Sora MC.* Potential of P40 plastination for morphometric hip measurements. Surg Radiol Anat 2005; 27(2): 147–51.
19. *Aktas S, Pekindil G, Ercan S, Pekindil Y.* Acetabular dysplasia in normal Turkish adults. Bull Hosp Jt Dis 2000; 59(3): 158–62.
20. *Massie WK, Howorth MB.* Congenital dislocation of the hip. Part. I. Method of grading results. J Bone Joint Surg Am 1950; 32–A(3): 519–31.
21. *Nakamura S, Ninomiya S, Nakamura T.* Primary osteoarthritis of the hip joint in Japan. Clin Orthop Relat Res 1989; (241): 190–6.

Received on May 14, 2010.
Revised on April 29, 2011.
Accepted on April 29, 2011.