ORIGINAL ARTICLE

Eur. J. Anat. 22 (5): 397-402 (2018)

Morphological variation of the femoral head fovea capitis

Andreas Bertsatos, Maria-Eleni Chovalopoulou, Klitemnistra Giannaki, Efstratios Valakos

Department of Animal and Human Physiology, Faculty of Biology, School of Sciences, National and Kapodistrian University of Athens, Panepistimiopolis, GR 157 81 Athens, Greece

SUMMARY

The *fovea capitis femoris* receives the distal attachment of the *ligamentum teres femoris*. Although recent research has shown that the latter may have a number of functions including mechanical stability to the hip joint, there is little published information on the morphological variation of the *fovea capitis femoris*. The present study investigates the morphological variation of the *fovea capitis femoris* with respect to sex and age. Morphometric properties were recorded from both left and right femurs of 212 individuals from the Athens skeletal collection. The *fovea capitis femoris* was photographed *en face* with a reference scale and a polyline outlining its boundary edges was extracted. Two shape variables and three size variables of the *fovea capitis femoris* were calculated and used in the morphological analysis. Two variables, one size and one shape variable, exhibited bilateral asymmetry. The sexual dimorphism of *fovea capitis femoris* is attributed to size variables, while at the same time there are age-related changes in its shape. The *fovea capitis* area and the *fovea capitis* maximum diameter have significant higher values in males, while the perimeter of *fovea capitis* tends to have a more irregular shape in older individuals. However, *fovea capitis femoris* cannot be used for age estimation or sex determination of a human skeleton.

Key words: Fovea capitis – Morphometric properties – Size and shape variation – Sex and age related variation – Age estimation – Sex determination

Corresponding author: Andreas Bertsatos. Dept. of Animal and Human Physiology, National and Kapodistrian University of Athens, Panepistimiopolis, GR 157 81 Athens, Greece.
E-mail: abertsatos@biol.uoa.gr

INTRODUCTION

The main function of the *ligamentum teres femoris* is to provide a functional blood supply to the femoral head (Brewster, 1991; Gray and Villar, 1997) in the fetus. Although it remains unclear whether this role is retained through into adulthood (Chatha and Arora, 2005; Byrd, 2013; Chang and Huang, 2013), recent studies have suggested that the *ligamentum teres* may contribute to stability of the hip joint (Bardakos and Villar, 2009; Cerezal et al., 2010). The *ligamentum teres* is reported to be tensioned in combined flexion–adduction–external rotation of the hip joint (Gray and Villar, 1997; Bardakos and Villar, 2009; Chung, 1976). It extends from the edges of the acetabular notch, to the fovea capitis on the head of the femur (Cerezal et al., 2010; Crelin, 1976).

The *fovea capitis femoris* (FCF) is located slightly posterior and inferior to the center of the articular surface of the femoral head (Michaels and Matles, 1970; Wenger et al., 2007). In contrast to other ligament attachment sites, the FCF is represented as focal depression and is typically slightly ovoid, with an oblique, superior-to-posteroinferior orientation (Bardakos and Villar, 2009). The receptacle zone of the FCF, the smooth lower half, is said to help accommodate the fibers of the *ligamentum teres* when it is tensed (Bardakos and Villar, 2009; Rao et al., 2001), which is thought to contribute to its shape (Kapandji, 2007). Although in adults the *ligamentum teres* is occasionally absent on one or both sides (Tan and Wong, 1990), the FCF is a consistent entity (Tan and Wong, 1990; Cerezal et al., 2012). Even in cases of congenital absence of the *ligamentum teres*, the FCF is present although hypoplastic (Cerezal et al., 2010).

The FCF is used as a marker in various studies

Submitted: 15 April, 2018. *Accepted:* 19 June, 2018.

and its morphology has been evaluated for several anthropological enquiries. When measuring variations of the acetabular orientation through image analysis, the FCF is a standard landmark (Beltran et al., 2012). Additionally, the FCF serves as a marker for evaluating dysplastic hips (Siebenrock et al., 2013). From an anthropological perspective, the FCF's morphology, apart from being used for differentiation of long bone fragments from each other even in juveniles (Scheuer et al., 2004; Bass, 2005), recently has also been evaluated for sex determination of an individual (Murton et al., 2015). However, there has been very little research reported on the anatomy of the FCF (Perumal et al., 2017; Acar et al., 2017).

The present study aims to contribute to the existing literature by evaluating whether the *fovea capitis femoris* can be used for age-at-death estimation or sex assessment of a human skeleton. More specifically, the present study evaluates the variation in size and shape of the FCF with respect to age and sex using dry femora.

MATERIALS AND METHODS

For the purpose of this research 212 individuals (120 males and 92 females) were studied from the Athens Collection. The Athens Collection is housed in the Department of Animal and Human Physiology of the University of Athens. All individuals were acquired from cemeteries in the Athens area, are Greek nationals, with the vast majority born in Greece, and their respective years of birth span from 1879 to 1965. Information on the name and age at death of each individual in the collection is derived from death records (Eliopoulos et al., 2007). Adult individuals without any evidence of pathology or morphological deformities in femoral head were selected.

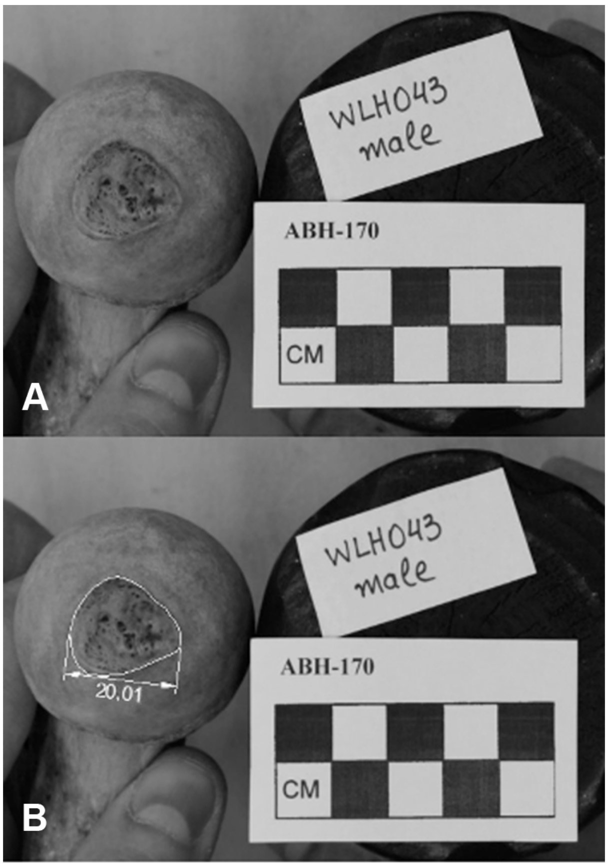

Fig 1. A: The fovea capitis femoris (FCF) photographed in face with a reference scale. **B**: The fovea capitis maximum diameter and the polyline outlining the boundary edges of the FCF.

Data acquisition

Morphometric properties were recorded from both left and right femora. A Mitutoyo 150 mm dial caliper (graduation 0.02 mm) was used for the measurement of the femoral head's maximum diameter (FHMD) and a Canon EOS 100D camera with Canon EF 40 mm f / 2.8 STM fixed focal length lens for image acquisition of the *fovea capitis femoris* (FCF). All FCF images were shot from a stationary position with a vertical camera view perpendicular to the reference scale at a fixed distance of 35 cm. All femoral samples were manually positioned with the FCF surface facing upwards and at the same plane with the reference scale as shown in Fig. 1. The 2D coordinates of a polyline outlining the boundary edges of the FCF were extracted using AutoCAD software. In order to evaluate the reproducibility of the digitization method, 10 femoral samples were positioned and photographed twice and polylines were extracted from both sets by the same observer. Additionally, polyline extraction by two different observers was further performed on 10 FCF images. Nevertheless, the sample of extracted polyline 2D coordinates used in the analysis of FCF's morphological variation was digitized by the same observer.

In total, 5 variables (2 shape variables and 3 size variables) were used in order to investigate the variation of the FCF. More specifically, the 3 size variables used in our study are the *fovea capitis* area (FCA) and the maximum diameter (FCMD) of the FCF, as well as the ratio of the *fovea capitis* area to the femoral head surface (FCA/FHS). The FCA/FHS ratio is expressed in percentage and the femoral head surface (FHS) was approximated as 74% of the sphere (Ruff, 1988) calculated from the FHMD as $4\pi r^2$. Shape variables comprise the following two ratios:

{ArPerIndex $\in R:0<x\leq 1$}: the ratio of the area to the squared perimeter of the *fovea capitis* multiplied by 4π so that ArPerIndex reaches maximum when *fovea capitis* is perfectly circular.

{SMA $\in R:0<x\leq 1$}: the ratio of the minimum (I_{MIN}) to the maximum (I_{MAX}) principal component of second moments of area of the FCF, which maximizes when *fovea capitis* area is evenly distributed across principal axes and as close as possible around its centroid.

The FCA, its perimeter, the FCMD, as well as the I_{MAX} and I_{MIN} were calculated with GNU Octave from the coordinates of the recorded polylines (Fig. 1). The three ratios were also calculated with GNU Octave. Regarding intra- and inter-observer error, the mean absolute difference (MAD) between repeated digitized polylines was calculated for the FCA and FCMD variables.

Statistical analysis

Prior to any statistical analysis, a Kolmogorov-Smirnov test was conducted in order to determine whether parametric or non-parametric test will be used. Initially, paired sample t-test or Wilcoxon test (non-parametric), depending on the results of the normality test, was performed in order to test for bilateral asymmetry and whether the left and right sides should be analyzed separately. Independent sample t-test or Mann-Whitney test (non-parametric) was used in order to evaluate the presence of sexual dimorphism in the FCF. Additionally, the sample was divided in 3 age group categories: 1) 20-39 years old, 2) 40-59 years old and 3) ≥60 years old and tested for age related changes through either ANOVA or Kruskal-Wallis H test (non-parametric). The specific age ranges were chosen for similar size of each subgroup based on the availability of our sample, while they are still representative of young-aged, middle-aged, and old-aged groups of individuals. In cases where statistically significant difference was detected, Dunn's Test, with Bonferroni adjusted p values, was used to pinpoint which specific groups differ significantly from the others. Finally, the appropriateness of the *fovea capitis femoris* as a sex and age estimator was evaluated through Discriminant Function Analysis (DFA). SPSS software (PASW Statistics 23.0) was used to perform all statistical analyses.

RESULTS

Regarding the reproducibility of the digitization method in the present study, the MAD concerning intra-observer error was found approximately 0.05 mm for FCMD and 2 mm^2 for FCA, whereas for inter-observer error the MAD values were 0.08 mm and 2.5 mm^2, respectively. Considering the overall observed variability of the FCMD and FCA variables in our sample, as shown in table 1, the intra- and inter-observer errors may be regarded as negligible.

All 5 FCF variables, for male and female groups separately, were tested for bilateral asymmetry. According to the Kolmogorov–Smirnov test, the ArPerIndex variable of the left side both for males and females failed the normality test (p-values: <0.001 and 0.019 for males and females respectively). The SMA variable of the left side for females also failed the normality test (p-values: 0.034). Consequently, the Wilcoxon test was performed for the ArPerIndex variable for both sexes, as well as the SMA variable for the female group, while in all other cases the paired sample t-test was performed. The FCA/FHS and SMA variables exhibited bilateral asymmetry in females. Henceforth, the left and right sides were analyzed separately for these variables, whereas the average values of the left and right side of the FCA, FCMD and ArperIndex variables were used for the subsequent analyses.

Table 1 presents the descriptive statistics for all 5 FCF variables analyzed with respect to sex and age. In most of the size variables males exhibit higher values than females, the exception concerns the ratio of the *fovea capitis* area to the femoral head surface. In case of the shape variables the reverse applies. However, regarding the FCA/FHS variable as well as the shape variables, the differences between sexes are small, when considering the confidence intervals for their mean values. These observations are confirmed by the evaluation of the presence of sexual dimorphism.

Table 1. Summary statistics for the femoral head fovea capitis variables. FCA in mm2; FCMD in mm.

		N	*Mean*	*Std. Deviation*	*95% Confidence Interval for Mean*		*Kolmogorov-Smirnov*
					Lower Bound	*Upper Bound*	*Sig.*
FCA	Males	*120*	*219.939*	*64.738*	*207.410*	*232.468*	*.200*
	Females	*92*	*177.565*	*48.299*	*166.952*	*188.177*	*.181*
FCMD	Males	*120*	*19.959*	*3.034*	*19.372*	*20.546*	*.200*
	Females	*92*	*17.874*	*2.737*	*17.273*	*18.475*	*.200*
ArPerIndex	Males	*120*	*0.873*	*0.043*	*0.864*	*0.881*	***.013***
	Females	*92*	*0.880*	*0.039*	*0.871*	*0.889*	*.200*
SMA (Left side)	Males	*120*	*0.588*	*0.133*	*0.562*	*0.614*	*.200*
	Females	*92*	*0.608*	*0.155*	*0.574*	*0.642*	***.034***
SMA (Right side)	Males	*120*	*0.564*	*0.142*	*0.537*	*0.592*	*.200*
	Females	*92*	*0.571*	*0.134*	*0.541*	*0.601*	*.200*
FCA/FHS (Left side)	Males	*120*	*4.336*	*1.241*	*4.096*	*4.576*	*.200*
	Females	*92*	*4.498*	*1.168*	*4.242*	*4.755*	*.092*
FCA/FHS (Right side)	Males	*120*	*4.207*	*1.268*	*3.962*	*4.453*	*.200*
	Females	*92*	*4.287*	*1.255*	*4.011*	*4.563*	*.200*

FCA: fovea capitis area; FCMD: fovea capitis maximum diameter; ArPerIndex: ratio of the area to the squared perimeter of the fovea capitis multiplied by 4π; SMA: ratio of the I_{MIN} to the I_{MAX} principal components of second moments of area of the FCF; FCA/FHS: ratio of the fovea capitis area to the femoral head surface expressed in percentage.

Table 2 presents the independent sample t-test results regarding the presence of sexual dimorphism in the *fovea capitis femoris* variables. In males the ArPerIndex variable and in females the SMA variable of the right side, failed the normality test (K-S sig. Males: 0.013; Females: 0.034). Consequently, a Mann-Whitney test was performed for these variables.

According to the results, only the size variables FCA and FCMD are sex dimorphic. Applying discriminant function analysis on the FCA and FCMD variables resulted in significant models for both variables (Wilk's lambda: 0.888 and 0.884 respectively; $p < 0.001$ for both). The cross-validated classification accuracy ranges from 62.7% to 65.6% for the FCA and FCMD variables respectively (Table 3).

Regarding the FCF's size and shape changes related to aging process, the FCA and the FCMD were evaluated separately for males and females since they exhibit sexual dimorphism, while the SMA, the FCA/FHS and the ArPerIndex were evaluated for the total sample. Regarding the results of the Kruskal-Wallis H test or the ANOVA, depending on the results of the normality test (Table 4), only the ArPerIndex exhibits statistically significant difference ($p = 0.028$) between age group categories. Finally, Dunn's pairwise tests adjusted by Bonferroni correction revealed statistically significant difference ($p = 0.025$) only between the age groups of «20-39 years old» and «≥60 years old» in the ArPerIndex variable.

DISCUSSION

Very few studies in the literature have focused on the anatomy of the FCF, even though the femur is widely used in anthropology (Bass, 2005). The present study evaluated the sex- and age-related morphological variation of the FCF using a number of variables that accurately represent its size and shape properties and aimed to assess whether the *fovea capitis femoris* can be used for sex and/or age-at-death estimation of a human skeleton. Perumal et al. (2017) analyzed the morphology and morphometry of the FCF on 125 dry adult femurs (61 right and 64 left) from the Anatomy Museum of the University of Otago in New Zealand. They photographed the FCF *en face* with a reference scale and they recorded the maximum and the minimum length (LL: longitudinal length and TL: transverse length respectively), as well as the cross-sectional area (CSA) of the FCF using the ImageJ software. According to Perumal et al.'s research, the LL and CSA mean values of the FCF were 1.8 cm and 1.8 cm^2 respectively. These findings are similar to the results of our research regarding the FCMD and FCA variables respectively in the female group. Unfortunately, Perumal et al. (2017) were not able to classify the bones based on sex, due to lack of demographic data. Additionally, Perumal et al. (2017) found that 17% of the femoral head was occupied by the FCF with the use of the

$$\frac{Cross-sectional\ area\ of\ the\ FCF}{Cross-sectional\ area\ of\ the\ head\ of\ the\ femur}$$

ratio. In our study, as determined by the FCA/FHS ratio, only 4.21% and 4.29% of the femoral head is occupied by the FCF in males and females respectively. This disagreement with Perumal et al. (2017) is due to the different approaches used for femoral head surface estimation. Nevertheless, we consider the estimate used in the present study more accurate based on Ruff, who reported it to be approximately 74% of the sphere calculated by the FMHD (Ruff, 1988) as opposed to the cross-sectional area utilized by Perumal et al. (2017).

Sampatchalit et al. in 2009 used 11 cadaveric hip joints (8 males and 3 females) in order to examine the degenerative changes in the *ligamentum teres* of the hip with magnetic resonance arthrography, anatomical inspection and histological evaluation. According to their results, the maximum width of the *fovea capitis* ranges from 12 to 15 mm in males and 13 to 16 mm in females. In our sample, the mean values of the FCMD are higher for both sexes. This disagreement with our study is more likely due to the small sample size used by Sampatchalit et al. (2009) in their research rather than differences between populations.

Murton et al. (2015) used the maximum *fovea capitis* height (MFCH: the distance between the most superior and the most inferior points on the FCF), as well as the maximum *fovea capitis* breadth (MFCB: the distance between the most medial and the most lateral points on the FCF) and calculated the *fovea capitis* index using the formula: *(MFCH x 100)/MFCB*, in order to establish a new method for sex determination. Measurements

Table 2. Results of Independent sample t-test (A) and Mann-Whitney test (B) regarding the presence of sexual dimorphism in the fovea capitis femoris variables.

A)	*t*	*df*	*Sig.*
FCA	*5.335*	*208*	***<.001***
FCMD	*5.151*	*209*	***<.001***
SMA (Right side)	*-0.788*	*196*	*.431*
FCA/FHS (Left side)	*-0.969*	*198*	*.334*
FCA/FHS (Right side)	*-0.773*	*196*	*.440*
Significant difference (p≤0.05)			

B)	*Mann-Whitney U*	*Sig.*
ArPerIndex	*4778*	*.114*
SMA (Left side)	*4696*	*.589*
Significant difference (p≤0.05)		

FCA: fovea capitis area; FCMD: fovea capitis maximum diameter; ArPerIndex: ratio of the area to the squared perimeter of the fovea capitis multiplied by 4π; SMA: ratio of the I_{MIN} to the I_{MAX} principal components of second moments of area of the FCF; FCA/FHS: ratio of the fovea capitis area to the femoral head surface expressed in percentage.

Table 3. Discriminant functions and correct classification results of FCA and FCMD variables.

	N	*Constant*	*Coefficient*	*Percentage of correct classification %*		
				Total[a]	*Males*[a]	*Females*[a]
FCA	*212*	*-3.271*	*0.016*	*62.7*	*69.2*	*54.3*
FCMD	*212*	*-6.375*	*0.333*	*65.6 / 65.1*	*75.8*	*52.2 / 51.1*

[a]Single values are given when original group classification equals cross-validated classification, otherwise both values are shown in the form: original group / cross-validated

FCA: fovea capitis area; FCMD: fovea capitis maximum diameter

were taken with a caliper. According to Murton et al.'s results (2015), although the MFCH and the MFCB didn't exhibit sexual dimorphism, when both variables were combined into an index of shape there were significant differences between sexes for both left and right sides. In our study the reverse applies. More specifically, according to our results, shape variables of the FCF are not sexually dimorphic, while the FCMD exhibits sexual dimorphism.

Acar et al. (2017) used x-ray views to record the FCF variant configurations and age-related changes according to the *fovea capitis* index:

$$FCI = \frac{Fovea\ Capitis\ Diameter \times 100}{Femoral\ Head\ Diameter}$$

The *fovea capitis* diameter was measured from its upper margin to its lower margin, while the femoral head diameter from the diameter of a complete circle around the femoral head.

According to Acar et al.'s results, the FCI does not exhibit sexual dimorphism. This observation is consistent with our results, since we did not find statistically significant differences between sexes regarding the FCA/FHS variable, which is equivalent to the Acar's FCI. However, Acar's FCI exhibited bilateral asymmetry in males, whereas in our research statistically significant bilateral asymmetry of the FCA/FHS variable was observed in females. This may be due to the morphological variation between populations.

Regarding the FCF's age-related changes, Acar et al. (2017) found statistically significant differences in FCI between the age group categories «20-39 years old» and «≥60 years old» as well as between the age group categories «40-59 years old» and «≥60 years old». More specifically, according to their results, the *fovea capitis* diameter increases with aging process. In our research, the mean value of the FCMD is almost the same in all age group categories in males, and while in females the FCMD mean value increases with aging process, the differences are not statistically significant. This disagreement with Acar et al.'s study (2017) may be due to the different techniques used to obtain the *fovea capitis* diameter. On the other hand, our research revealed that there are age-related changes in FCF's shape. According to our research, the perimeter of the *fovea capitis* tends to have a more irregular shape in older individuals (ArPerIndex decreases). This could be the result of bone proliferation related to the aging process (Boskey and Coleman, 2010), or presumably a combination of aging and activity patterns that may result to the observed morphological variation.

The present study utilizes certain size and shape variables that aim to describe the morphological variability of the FCF in a most representative way possible, while still maintaining an easily reproducible and accurate method. However, it should be emphasized that not all researchers have used the same methods or variables for studying the *fovea*

Table 4. Results of ANOVA (A) and Kruskal Wallis test (B) regarding age related changes of the fovea capitis femoris variables.

A)

	F	*df*	*Sig.*
FCMD (Male group)	*0.601*	*2 / 117*	*.550*
FCMD (Female group)	*0.662*	*2 / 89*	*.518*
SMA (Right side)	*0.041*	*2 / 196*	*.960*
FCA/FHS (Left side)	*0.801*	*2 / 198*	*.450*

Significant difference (p≤0.05)

Degrees of freedom are shown in the form: Between Groups /

B)

	Chi-Square	*df*	*Sig.*[a]
FCA (Male group)	*0.019*	*2*	*.991*
FCA (Female group)	*0.009*	*2*	*.996*
SMA (Left side)	*5.664*	*2*	*.059*
FCA/FHS (Right side)	*0.300*	*2*	*.861*
ArPerIndex	*7.137*	*2*	*.028*
	Dunn's pair-	***Median***	***Adj. Sig.***[b]
	20-39 / 40-59	*0.895*	*.511*
	40-59 / ≥60	*0.885*	*.593*
	≥60 / 20-39	*0.867*	*.025*

[a]Significant difference (p≤0.05)

[b]Significant difference adjusted using the Bonferroni correction (p≤0.05)

FCA: fovea capitis area; FCMD: fovea capitis maximum diameter; ArPerIndex: ratio of the area to the squared perimeter of the fovea capitis multiplied by 4π; SMA: ratio of the I_{MIN} to the I_{MAX} principal components of second moments of area of the FCF; FCA/FHS: ratio of the fovea capitis area to the femoral head surface expressed in percentage.

capitis, hence the aforementioned comparisons with previous studies is on a more general basis.

CONCLUSIONS

Our findings indicate that the size variables FCA and FCMD are sexually dimorphic, while at the same time the shape variable ArPerIndex exhibits age-related changes. However, as shown by the results of the discriminant function analysis and Dunn's pairwise tests, the magnitude of changes related both to sexual dimorphism and aging process is small, and therefore the *fovea capitis femoris* cannot be used for age-at-death estimation or sex assessment of an unidentified case. Nevertheless, further research including confounding factors such as mechanical stress and activity patterns may shed light to the morphological variation of the FCF, which, to our current understanding, for the most part may be considered idiosyncratic.

REFERENCES

ACAR N, KARAARSLAN A, KARAKASLI A, ERDURAN M (2017) Femoral head fovea capitis variant configurations and age related changes- a radiological study. *Iranian J Radiol*, InPress. doi:10.5812/iranjradiol.41130.

BARDAKOS NV, VILLAR RN (2009) The ligamentum teres of the adult hip. *J Bone Joint Surg*, 91-B(1): 8-15.

BASS WM (2005) *Human osteology: a laboratory and field manual*. Missouri Archaelogical Society, Columbia, p 223.

BELTRAN LS, MAYO JD, ROSENBERG ZS, TUESTA MD, MARTIN O, NETO LP, BENCARDINO JT (2012) Fovea alta on MR images: is it a marker of hip dysplasia in young adults? *Am J Roentgenol*, 199(4): 879-883.

BOSKEY AL, COLEMAN R (2010) Aging and bone. *J Dental Res*, 89(12): 1333-1348.

BREWSTER SF (1991) The development of the ligament of the head of the femur. *Clin Anat*, 4(4): 245-255.

BYRD JW (2013) *Operative hip arthroscopy*. Springer, New York, p 108.

CEREZAL L, ARNAIZ J, CANGA A, PIEDRA T, ALTÓNAGA JR, MUNAFO R, PÉREZ-CARRO L (2012) Emerging topics on the hip: Ligamentum teres and hip microinstability. *Eur J Radiol*, 81(12): 3745-3754.

CEREZAL L, KASSARJIAN A, CANGA A, DOBADO MC, MONTERO JA, LLOPIS E, ROLÓN A, PÉREZ-CARRO L (2010) Anatomy, biomechanics, imaging, and management of ligamentum teres injuries. *Radiographics*, 30: 1637-1651.

CHANG CY, HUANG AJ (2013) MR imaging of normal hip anatomy. *Magn Reson Imaging Clin N Am*, 21(1): 1-19.

CHATHA DS, ARORA R (2005) MR imaging of the normal hip. *Magn Reson Imaging Clin N Am*, 13(4): 605-615.

CHUNG S (1976) The arterial supply of the developing proximal end of the human femur. *J Bone Joint Surg*, 58(7): 961-970.

CRELIN ES (1976) An experimental study of hip stability in human newborn cadavers. *Yale J Biol Med*, 49: 109-121.

ELIOPOULOS C, LAGIA A, MANOLIS S (2007) A modern, documented human skeletal collection from Greece. *HOMO - J Comp Human Biol*, 58(3): 221-228.

GRAY AJ, VILLAR RN (1997) The ligamentum teres of the hip: an arthroscopic classification of its pathology. *Arthroscopy,* 13(5): 575-578.

KAPANDJI IA (2007) *The physiology of the joints*. Churchill Livingstone/Elsevier, Edinburgh, p 24.

MICHAELS G, MATLES AL (1970) 21 The role of the ligamentum teres in congenital dislocation of the hip. *Clin Orthop Rel Res*, 71(1): 199-201.

MURTON N, BORRINI M, ELIOPOULOS C (2015) Sexual dimorphism of the fovea capitis femoris in a medieval population from Gloucester, England. *Global J Anthropol Res*, 2(2): 9-14.

PERUMAL V, WOODLEY SJ, NICHOLSON HD (2017) The morphology and morphometry of the fovea capitis femoris. *Surg Radiol Anat*, 39(7): 791-798.

RAO J, ZHOU Y, VILLAR R (2001) Injury to the ligamentum teres. *Clin Sports Med*, 20(4): 791-800.

RUFF CB (1988) Hindlimb articular surface allometry in hominoidea and Macaca, with comparisons to diaphyseal scaling. *J Human Evol*, 17(7): 687-714.

SAMPATCHALIT S, BARBOSA D, GENTILI A, HAGHIGHI P, TRUDELL D, RESNICK D (2009) Degenerative changes in the ligamentum teres of the hip. *J Comput Assist Tomogr*, 33(6): 927-933.

SCHEUER L, BLACK S, CHRISTIE A (2004) *The juvenile skeleton*. Elsevier Academic Press, Amsterdam, p 355.

SIEBENROCK KA, STEPPACHER SD, ALBERS CE, HAEFELI PC, TANNAST M (2013) Diagnosis and management of developmental dysplasia of the hip from triradiate closure through young adulthood. *J Bone Joint Surg*, 95(8): 749-755.

TAN CK, WONG WC (1990) Absence of the ligament of head of femur in the human hip joint. *Singapore Med J*, 31: 360-363.

WENGER D, MIYANJI F, MAHAR A, OKA R (2007) The mechanical properties of the ligamentum teres. *J Pediat Orthop*, 27(4): 408-410.