Proximal Femoral Epiphysis Anatomy in Chilean Population. Orthopedic and Forensic Aspects

Anatomía del Epífisis Proximal del Fémur en la Población Chilena. Aspectos Traumatológicos y Forenses

[*]Horacio Osorio; [*]Karl Schorwer; [**]César Coronado; [***]Javier Delgado & [****]Pedro Aravena

SUMMARY: From a biomechanical standpoint, bone geometry and density are factors correlated to the bone resistance of the femur when supporting body weight, with geometric parameters like the diameter of the femoral head and neck, the length of the femoral neck, and the femoral neck angle as determinant factors in the incidence of hip fractures, which increase in frequency and seriousness in osteoporotic patients. In Chile, morphometric data that contributes to relating the anatomy of the proximal epiphysis of the femur as an associated factor in hip fractures does not exist; likewise, there are no anthropometric indexes that may contribute to the forensic sciences. The purpose of this study is to establish average measurements of the proximal epiphysis of the femur in the adult Chilean population. Descriptive Study. The proximal epiphyses of 81 dry adult femurs were analyzed (44 right and 37 left bones), measuring the following parameters: length of the femoral neck (LN), femoral neck angle (FNA), circumference of the femoral head (CH) and circumference of the femoral neck (CN). The statistical relationship between the measurements and the side of each sample was analyzed (t-test p=0.05). The average lengths were LN= 3.59cm (±0.43 cm); FNA= 124.17º (±6.37º), CH= 14.34 cm (±1.27 cm) and CN= 9.7 cm (±0.87 cm). No significant differences between the left and right sides were found. Average numbers were obtained for the anatomy of the proximal femoral epiphysis from a sample in the Chilean population. With the data obtained, we propose to carry out anatomo-clinical, epidemiologic and forensic studies in this population.

KEY WORDS: Anatomy; Femur head; Femur neck; Hip fractures.

INTRODUCTION

From a biomechanical standpoint, bone geometry and density are factors that correlate with bone resistance of the femur when supporting body weight. Geometric parameters, like the length of the femoral neck and the femoral neck angle (Malavolta *et al.*, 2003; Pulkkinen *et al.*, 2004), along with the diameter of the femoral neck and cortical thinning in the neck of the femur (Black *et al.*, 2008), are determining factors in the incidence of hip fractures, which increase in frequency and seriousness in osteoporotic patients (Gnudi *et al.,* 2004).

Hip fractures are common in elderly patients, and it is an important cause for disability, a current problem in public health, in a population that progressively grows older. The causes are multifactorial, but the major contributing factor is the reduction in the resistance of the proximal epiphysis of the femur, due mainly to osteoporosis, both primary and secondary (Orwoll *et al.*, 2009).

Fractures in the femoral neck have been vastly studied, and from their classification, it has been derived that there are stable and unstable fractures, divided in 4 groups that range from incomplete, to complete and displaced (Garden, 1961).

There are differences in the propensity to proximal femoral fractures in individuals of specific populations (Zang *et al.*, 2010), presenting data that suggests that white individuals have a comparatively higher propensity than Asians and those of African decent (population ≥ 65 years old) (Marshall *et al.,* 2008).

In Chile, the studies that currently exist only determine that the increment in the rates of hip fracture is associated with growing older (Valdivia *et al.*, 1996; Mautalen & Pumarino, 1997). However, there is no available data that contributes

[*] Department of Normal Anatomy. School of Medicine. Universidad de Concepción, Chile.
[**] Departamento de Morfofunción, Facultad de Medicina, Universidad Diego Portales, Chile.
[***] Institute of Locomotor System. School of Medicine. Universidad Austral de Chile, Chile.
[****] Institute of Anatomy, Histology and Pathology. School of Medicine. Universidad Austral de Chile, Chile.

to relating the anatomy of the proximal femoral epiphysis as a factor that is associated with hip fractures. Likewise, there are no anthropometric indexes that may contribute to the forensic sciences. The objective of this study is to describe the morphometry of the proximal epiphysis of the femur in Chilean adults from the Bio-Bio Region, in Chile.

MATERIAL AND METHOD

A descriptive study. Dry human femurs were analyzed in the laboratory of Human Anatomy at Universidad de Concepción in 2009. Adult bones without sex distinctions were included in the study. Bones with visible abnormalities, signs of degenerative osteoarthritis, areas with decalcification or loss of tissue due to manipulation were excluded. The analyzed parameters were the following (Fig. 1):

Circumference of the femoral head (CH): largest diameter of the femoral head.
Circumference of the femoral neck (CN): diameter of the femoral neck measured from the midpoint between the base of the femoral head and the intertrochanteric line.
Length of the femoral neck (LN): distance between the inferior region of the femoral head and the intertrochanteric line.
Femoral Neck Angle (FNA): angle between the major axis of the body, with the major axis of the femoral neck.

The lengths were measured with a 8" Mitutoyo caliper. For the circumferences, a metric tape in millimeters and for the FNA angle an standard goniometer was used. All measurements were recorded by the same observer.

Averages, standard deviations, and the minimum and maximum values were determined for all measurements. To verify the presence of differences in the variables under study between left and right femurs, we used a t-test with a significance level of 5%. The data was tabulated with the Microsoft Excel 2003 software, and analyzed with the statistical program STATA 10.0 (StataCorp LP. USA).
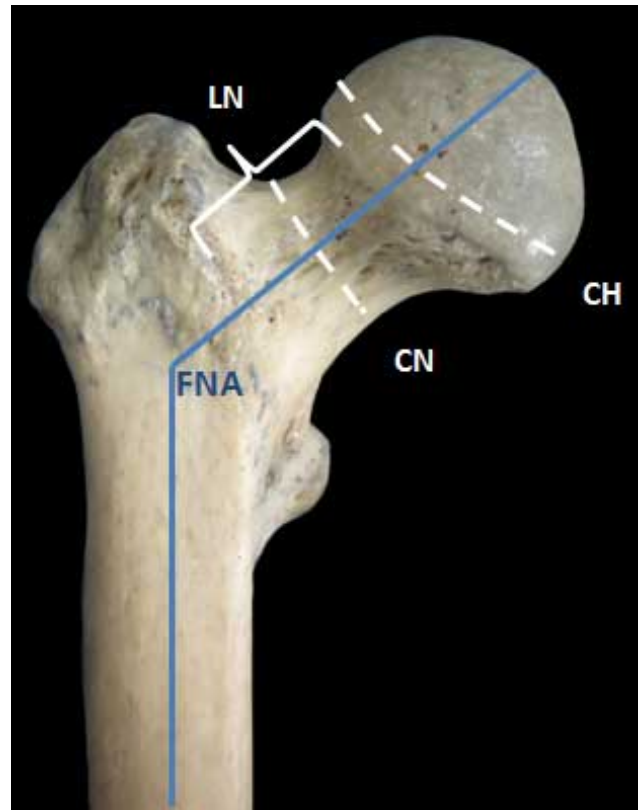

Fig. 1. Diagram of measurements of the proximal femoral epiphysis. CH: Circumference of the femoral head; CN: Circumference of the femoral neck; LN: Length of the femoral neck; FNA: Femoral Neck Angle.

RESULTS

In total, 81 human femurs were selected, 44 right and 37 left bones. The average lengths were LN= 3.59 cm (±0.43 cm); FNA= 124.17° (±6.37°), CH= 14.34 cm (±1.27 cm) and CN= 9.7 cm (±0.87 cm). No statistically significant differences were found in the circumference of the head (p=0.27), in the circumference of the neck (p=0.83), the FNA (p=0.77), and in the length of the neck (p=0.40), between left-side and right-side femurs (Table I).

Table I. Arithmetic means, standard deviations (±) and minimums and maximum values (min-max) of the circumference of head and neck, the length of the neck and angle of the femoral neck in centimeters, and the statistical relationship between right (n= 44) and left (n= 37) femurs.

Measures	Right (±)	Left (±)	Min-Max		Total (±)	p value
			Right	Left		
Circumference femoral head	14.49 (0.94)	14.17 (1.56)	12.4 - 16.1	8.13 - 16.9	14.34 (1.27)	0.27
Circumference of femoral neck	9.72 (0.81)	9.68 (1)	8 - 11.2	7.6 - 11.1	9.7 (0.89)	0.83
Femoral neck length	3.55 (0.41)	3.64 (0.44)	2.65 - 4.6	2.85 - 5.3	3.59 (0.43)	0.77
Angle of the femoral neck	124.3° (6.14°)	123.9° (6.71°)	113° - 144°	113° - 145°	124.17° (6.37°)	0.40

DISCUSSION

In this descriptive study, the proximal epiphyses of 81 dry femurs were analyzed; no significant differences in the size of the circumference of the femoral head, the size and thickness of the femoral neck, and the angle of the femoral neck were found between right-side and left-side samples. These results are concordant with the analysis done by Anderson & Trinkaus (1998), which determined that there are few bone patterns that define variations between the dominant leg and its counterpart. Studies in Brazilian femurs (Caetano *et al.*, 2007) present, on average, a 5º in the FNA angle. Likewise, Toogood *et al.* (2009) found a femoral neck angle of 129.23º (± 6.24º) in 375 femurs, coming from white and African races from the Cleveland Museum, USA; additionally, anteversion in the femoral head was found in femurs of more than 50 years of age.

Prasad *et al.* (1996) determined in India an average of 126.8º in the diaphysis-neck angle (± 3.1º) and an average length of the neck of 28.4mm (± 4.5 mm) and a femoral head diameter of 41.2mm (± 3.8 mm) which, differing from our results, did find statistically significant differences between the gender of the dried bones, though not from one side to the other. All these angles are within acceptable orthopedic ranges, and no femurs were found presenting coxa valga or vara.

Other anatomo-clinical studies undertaken through anteroposterior hip x-rays garner other results. In 150 healthy patients, Lecerf *et al*. (2009) obtained an average FNA of 129º (± 6º). Likewise, Umer *et al*. (2010) obtained similar results in the Pakistani population, where the femoral neck angle was on average 130.3mm (± 6.1 mm). Calis *et al*. (2004) observed in x-rays of Turkish female patients that the width of the femoral neck was 35 mm, along with an angle of 128.9º.

To observe the exactness and reliability of x-ray studies, Rubin *et al*. (1992) compared measurements obtained from anteroposterior hip x-rays and CT scans in 32 femurs. There, the average angle of the femoral neck was 122.9º (± 7.6º), finding an average distortion of 0.9 mm (± 1.4 mm) between measurements done through x-rays, and those done with CT scans.

Morphological data for the proximal epiphysis of the femur are essential in anthropological, forensic and clinic milieus. It is known that the ethnicity, heredity, climate and nutritional conditions of a population affect the length of the long bones and the height of a person. Calculating femoral length from the dimensions of the proximal end of the femur

has great potential for application in physical anthropology, medical jurisprudence and forensic identification of an individual (Prasad *et al.*). The FNA in the femur is zero at the time of birth, and develops in relationship with growth. Its development is linked to verticalization and learning to walk, and it reached definite values at age 8, closely related with the age of the subject and the length of the femur (Tadieu & Damsin, 1997). This is particularly evident in cases of diminished or lack of weight-bearing during development, as in cases of children with congenital hip dysplasia (Anderson & Trinkaus).

The use of these statistical calculations with logistic regressions allows obtaining the length of the femur, and therefore, of the individual, from proximal femoral fragments. The angle of the femoral neck relates significantly with the length of the neck, but not with the diameter of the femoral head. In general, short people will have shorter femurs, shorter femoral necks, and smaller FNA, and thus, a more oblique femoral neck. Therefore, it is justified to say that the taller the individual, the more pronounced the femoral neck will be (Isaac *at al.*, 1997), within normal orthopedic parameters.

The physical characteristics of the bone, like bone mass, size and geometry, microarchitecture, bone remodeling and previous fractures of the proximal epiphysis of the femur, allow predicting the risk for hip fractures in different populations (Valdivia, 1999). It has been established that the thickness in the femoral neck coincides with diminished production of endosteal bone, having as a result a loss of bone density (Bone Mineral Density – BMD), and a rise in sub periosteal bone, secondary to the production generated at growth (Dinçel *et al*., 2008). In a retrospective study, El-Kaissi *et al*. (2005) demonstrated that Caucasian postmenopausal women with hip fractures have a longer length and axis of the femoral neck, compared to women without fractures, determining that, independent of their age, height and bone density, the risk of hip fracture increases by 24% with every one millimeter increase in the thickness of the femoral neck. Calis *et al*. obtained a similar result in Turkish women, where the angle and width of the femoral neck were significantly greater in patients with hip fractures.

In Chile, the incidence of hip fracture increases with age, 90% of them occurring in patients over 50. The mean age for cases is 80, with 2 to 3 times more incidence in women. Most frequent are femoral neck and trochanteric fractures, representing 90% of documented cases (Muñoz

et al., 2008). In 1996, at seven public hospitals in Santiago, Chile, 47% of reported fractures were on the left side, observing that rates increase strongly, influenced by age and gender factors (Valdivia *et al.*).

Sapunar *et al*. (2003) make an exhaustive analysis of the Mapuche ethnic influence in the incidence of hip fractures. In it, the clear predominance of the female gender is noteworthy, as is the significantly less portion of Mapuche individuals among patients with fractures. It shows that Mapuche ethnicity is a protective factor for proximal femur fractures (OR: 0.37; IC: 95% 0,177-0.77 y p= 0.0076), compared with non-Mapuche patients residing in urban sectors. This may be attributed to higher levels of physical activity and hard labor, and a lower incidence of smoking in this population. The existing relationship between osteoporosis and the thickening of the femoral neck, femoral morphology and its geometric disposition continue to be a matter of study, becoming progressively more interesting in the context of an increasingly older population pyramid. Likewise, there is an interest in modifying bone architecture with drugs that inhibit osteoclastic activity, but still fractures with increasingly complex treatments continue to occur, reason why the study of bone architecture and its understanding as a biological entity and not merely a structural one still are relevant topics.

Average values in the anatomy of the proximal epiphysis of the femur in the Chilean population were obtained. No significant differences were found between left and right bones. The data garnered may contribute to the analysis of causal factors for hip fractures in Chile, which as has been analyzed, may determine predictive values in the study of at-risk populations. In addition, it may also contribute with morphometric data about a bone structure in the superior limb, which may by useful in the analysis of forensic bone remains in Chilean population.

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RESUMEN: Desde un punto de vista biomecánico, la geometría y la densidad ósea son factores correlacionados con la resistencia del hueso del fémur al apoyar el peso corporal, con los parámetros geométricos, como el diámetro de la cabeza femoral y el cuello, la longitud del cuello del fémur, y el ángulo del cuello femoral factores determinantes en la incidencia de fracturas de cadera, que aumentan en frecuencia y gravedad en los pacientes con osteoporosis. En Chile, no existen datos morfométricos que relacionen la anatomía de la epífisis proximal del fémur como un factor asociado a las fracturas de cadera ni índices antropométricos que pueden contribuir a las ciencias forenses. El propósito de este estudio es establecer las medidas promedio de la epífisis proximal de fémur en población adulta chilena. Estudio Descriptivo. Se analizaron la epífisis proximal de 81 fémures adultos secos (44 derechos y 37 izquierdos), midiendo los siguientes parámetros: longitud del cuello femoral (LC) , ángulo cérvico-diafisiario femoral (ACD), circunferencia de la cabeza femoral (CCa) y circunferencia del cuello femoral (CCu). Se analizó la relación estadística de las medidas con el lado de cada muestra (test Chi cuadrado p:0,05) Las longitudes promedios fueron LC: 3,59 cm (±0,43 cm); ACD: 124,17º (±6,37º cm); CCa: 14,34 cm (±1,27 cm) y CCu: 9,7 cm (±0,87 cm). No se encontraron diferencias significativas entre el lado derecho e izquierdo. Los resultados proponen la necesidad de realizar estudios anatomo-clínicos y epidemiológicos actualizados en población chilena donde la geometría de la epífisis proximal del fémur se incluya dentro del análisis.

PALABRAS CLAVE: Anatomía; Cabeza femoral; Cuello femoral; Fractura de cadera.

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Correspondence to:
Pedro Aravena
Campus Isla Teja s/n
Valdivia
CHILE

Phone: +56-63-221205

Email: paravena@uach.cl