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SHORT COMMUNICATION

The external phenotype of the proximal femur in Portugal during the 20th century

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ABSTRACT

Bi-dimensional geometrical parameters of the proximal femur (femoral neck axis length, femoral neck width and neck-shaft angle) were evaluated in three identified Portuguese skeletal samples (Coimbra Identified Skeletal Collection; Luis Lopes Collection, Lisbon; and Identified Skeletal Collection of the 21st Century, Santarém) aiming to discern secular trends (considering individual years of birth and death) in the proximal femur phenotype throughout the 20th century in Portugal. The association of the so-called osteoporotic fractures (hip, vertebral, proximal humerus and distal radius fractures; N=89/492; 18,1%) with proximal femur geometry was also evaluated. It was not detected a definite secular trend in the proximal femur geometry during the last century. Notwithstanding, femoral neck width in the females pooled sample is significantly associated with osteoporotic fractures.

Keywords: bone geometry; femur; osteoporotic fractures; osteological reference collections; Portugal

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RESUMO

Três parâmetros bidimensionais do fémur proximal (comprimento do colo femoral, largura do colo do fémur e ângulo colodiafisário) foram analisados em colecções osteológicas de referência Portuguesas (Colecção de Esqueletos Identificados do Museu Antropológico da Universidade de Coimbra, Colecção "Luís Lopes" do Museu de História Natural de Lisboa e Colecção Identificada do Séc. XXI de Santarém) com o intuito de identificar modificações ao longo do séc. XX (tendência secular, considerando os anos de nascimento e morte) no fenótipo do fémur proximal. Foi também avaliada a associação das fracturas osteoporóticas (anca, corpo vertebral, úmero próximal e rádio distal; N=89; 18,1%) com a geometria do fémur proximal. Não foi detectada uma tendência secular clara na geometria do fémur proximal ao longo do último século. Contudo, a largura do colo do fémur encontra-se significativamente associada com a presença de fracturas osteoporóticas no grupo feminino.

Palavras-chave: geometria óssea; fémur; fracturas osteoporóticas; colecções osteológicas de referência; Portugal

Introduction

Bone continuously adapts to biomechanical stress (Frost, 2003). Wolff (1892) recognized that the geometrical properties of bone could be depicted under a wide-ranging principle, the famed Wolff's law, in which healthy bone changes and adjusts to the loads that affect it. Likewise, Roux proposed that the functional adjustment of trabecular bone is self-regulated, with bone cells responding to local mechanical stimuli (Gosman and Stout, 2010). Harold Frost suggested that bone design is under the control of a biomechanical system, the mechanostat (Frost, 1996; Frost, 2003). The pressure exerted by external interfering factors, such as age, individual weight or workloads, activates a feedback control loop and bone adapts its biomechanical properties according to the mechanical function, i.e., bone mass and geometry and consequently bone strength.

Fragility fractures (i.e., osteoporotic fractures) are more prevalent in aged individuals, especially women, with low bone mass (Curate et al., 2011; Curate et al., 2013a). Bone geometry is also a potential risk factor for fractures, increasing or diminishing bone strength and the proclivity to fall (Gregory and Aspden, 2008; Mourão and Vasconcellos, 2001). As such, we assessed bi-dimensional geometrical parameters of the proximal femur in three identified

Portuguese skeletal samples aiming to discern secular trends (considering individual years of birth and death) in the proximal femur phenotype throughout the 20th century in Portugal. The association of the so-called osteoporotic fractures with proximal femur geometry was also evaluated.

Materials and Methods

Well-preserved proximal femora were obtained from three documented Portuguese skeletal collections (Coimbra Identified Skeletal Collection [CISC], N=196 [♀: 98 / ♂: 98]; Lisbon Luis Lopes Collection [LC], N=260 [♀: 120 / ♂: 140]; and Santarém Identified Skeletal Collection of the 21st Century [SC], N=36 [♀: 22 / ♂: 14]). There is substantial overlap in the years of birth and death between the three samples (Curate et al., 2013a; Curate et al., 2013b; Cardoso, 2006). As such, the samples were pooled together and geometrical properties were evaluated against years of birth and death to identify possible secular trends. All individuals were born between 1825 and 1967, and died between 1891 and 2001. For the gross anatomic depiction of the proximal femora, femoral neck axis length (FNAL, the linear distance measured from the base of the greater trochanter [A] to the apex of the femoral head [B]), neck width (FNW, C-D) at the narrowest section of the neck (Fig. 1), and the neck-shaft angle between long axes of oblique femoral neck and shaft (NSA, Fig. 1) were measured with a calliper or goniometer, as appropriate. The statistical linear dependence between variables (e.g., FNAL and year of birth) was evaluated with the Pearson product moment correlation coefficient (Pearson's r) correcting for femoral physiological length (FPL). Classical osteoporotic fractures (hip, distal radius, proximal humerus and vertebral fractures) were recorded according to clinical and paleopathological protocols (Curate et al., 2011; Genant et al., 1992; Redfern, 2010). Binomial logistic regression (Forward: LR method) was used to measure the relationship between a categorical dependent variable (osteoporotic fractures presence/absence) and five independent variables (age at death, FNAL, FNW, NSA and FPL).

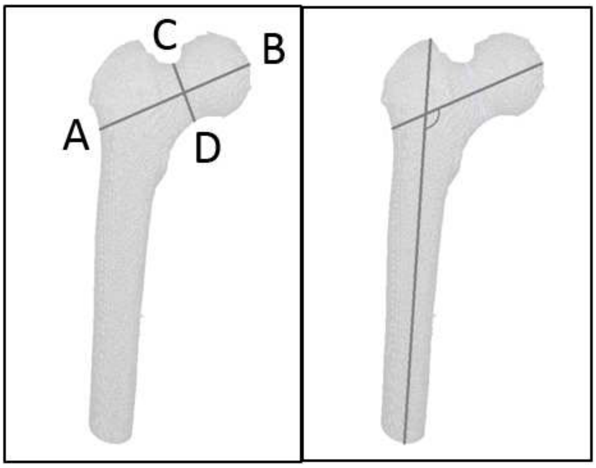

Figure 1: Femoral neck axis length (A-B) and neck width (C-D) (left); neck-shaft angle (right).

Results

There is a significant but weak negative association between year of birth and FNAL in the pooled females sample (Pearson's $r = -0.148$, $p=0.023$). The linear relationship between year of birth and NSA is also statistically significant, and the association is weak and positive (Pearson's r = 0.182, p=0.005). In the male group, the linear relationships between the geometrical properties of the proximal femur and year of birth are non-significant, as well as the association between FNW and year of birth in females. The linear relationships between the geometric variables of proximal the femur and the year of death are all non-significant in both sexes.

The prevalence of fragility fractures in the pooled sample is 18.1% (89/403). The fractures frequency in the female group (20.4%; 49/240) is higher than in males (15.9%; 40/252) but the difference is non-significant (Fisher's exact test: p=0.199). In the females, logistic regression showed that the variables «age at death» (B=0.042; Wald=16.435; p<0.001) and «FNW» (B=0.191; Wald=5.777; p=0.016) exercised a significant effect on the probability of displaying an osteoporotic fracture. In the male group, only «age at death» exerted a significant effect on the probability of having a fracture (B=0.037; Wald=13.066; p<0.001).

Discussion

The structural geometry of the proximal femur provides a good proxy for the quantification of bone strength, being congruent with the biomechanical stress, according to Wolff's law and the mechanostat theory (Melton III et al., 2005). Bone strength is subjected, not only to its qualitative and quantitative composition, but also to its structural phenotype (Travison et al., 2008). As such, it was theoretically expected that lifestyle conditions, such as physical activity and workloads, would influence the risk for fractures through bone architecture.

Also, it was anticipated that the geometrical phenotype of load bearing bones, like the femur, modify at a population-level with time, influenced by different levels of work and physical activity. Anyway, it was not detected a definite secular trend in the proximal femur geometry during the last century, although there is a weak association between FNAL and NSA with year of birth in the female group. FNAL (controlling for femur physiological length, which functions as a proxy for stature) appears to decline marginally. This is somewhat unexpected since there is a secular trend pointing to an increase in the length of the femoral neck axis in the last decades (Siëvanen et al. 2007). Nonetheless, most of the females in the pooled sample were born during the first decades of the 20th century, well before the betterment of the general health conditions of the Portuguese population (Veiga et al., 2004) and the overall mechanization of work. The neck-shaft angle becomes slightly more obtuse. This finding was epidemiologically anticipated since higher angles have been generally linked to sedentary living and the mechanization of work in recent populations (Anderson and Trinkaus, 1998).

Although some studies suggest that geometric parameters of the proximal femur are significantly associated with the risk of hip fractures, the epidemiological results are inconsistent (Gregory and Aspden, 2008). In this study, the width of the femoral neck is associated with the archetypal fragility fractures (taken together) but only in females. Nonetheless, it is important to note that the selected morphometric measurements are only an imperfect proxy for the proximal femur external phenotype. Also, bone architecture influences dissimilarly fractures in the hip or in the vertebral bodies, for example. As such, another study design (with more individuals) must contemplate the different types of fragility fractures independently.

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