Influence of Mechanical Loading and Skeletal Geometry in Bone Mass at the Proximal Femur in 10-12 Year Old Children - A Longitudinal Study

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Introduction
Osteoporosis is an underlying etiological factor in most hip fractures in elderly people [1, 2]. Sex differences in hip fracture risk have been attributed largely to a lower peak adult bone mass in females and women’s accelerated bone loss following the menopause [3]. However, sex-specificities in bone morphology and mechanical competence may also contribute to rate differences in two main types of hip fracture [4, 5]. Geometric measures of the proximal femur and its subchondral bone have been associated with hip fracture risk in adults [6-8]. These observations suggest the anatomy of the proximal femur and the pelvis are potential determinants of the type of hip fracture. As clear sex differences in hip kinematics and muscle activity during walking and running have been observed [9, 10], and as physical activity (PA) is one of the determinants of the loads exerted on the proximal femur, it is reasonable to formulate the hypothesis that the geometry of the pelvis and the hip may be associated with sex-specific mineralization patterns of the proximal femur. The aim of our study was to: a) analyse the effects of PA and pelvic proximal femur geometry on bone mass distribution at the proximal femur; and b) to investigate whether sex specific geometric variables influence sex-specific bone mass distribution patterns. We hypothesised that higher positional misalignment might be an artefact of sex-related biomechanical differences that influence loading at different regions of the proximal femur.

Methods
Subjects. 10 to 12 years children recruited from schools; all participants were healthy Caucasian students not taking any medication known to influence bone metabolism; all the participants evaluated twice at baseline and at the end of one year follow-up.

Proximal femur analysis. BMDs of the left proximal femur evaluated using DXA (QDR Experior: Hologic, Waltham, MA, USA). Three BMD ratios were calculated as indications of bone mass distribution of the proximal femur: FN/PP = femoral neck BMD/total proximal femur BMD; TR/PP = total hip BMD/total proximal femur BMD; IM/SL = anatomical femoral canal BMD/proximal femoral canal BMD. Inter-arterial distance and abductor lever arm. Images of whole body and left hip obtained for all children using DXA to determine the inter-arterial distance and abductor lever arm, respectively, using the CoreDirectX software (Coral Corporation, Ottawa, Ontario, Canada); linear geometric measures of the pelvis included the lower inter-arterial distance (LAD) (CD in Fig 1); the upper inter-arterial distance (UAD) (AB in Fig 1), and the inter-arterial distance (A/CD in Fig 1); the path of the abductor muscles represented by a tangential line to the lateral margin of the greater trochanter which was parallel to the line between the highest point on the greater trochanter and the femoral head (point C in Fig 2); the inferior line of this section (point C in Fig 2); the abductor lever arm is represented by the perpendicular distance between that tangent of the greater trochanter and the center of rotation of the femoral head.

Pelvic and Proximal Femur DXA Image

Habitual physical activity. PA assessed with the Actigraph accelerometer (model GT1M); intensity of PA was defined to the counts per minute (cpm) as follows: sedentary activity, up to 100 cpm; light intensity (LI)-1295 to 2955 cpm; moderate intensity (MI)-2956 to 4091 cpm; and vigorous intensity (VI)-over 4012 cpm [50]. Current and historical physical activity participation relevant to the musculoskeletal anatomy is also reported.

Body size and body composition. Standing and sitting height measured with a stadiometer (Recce 770, Hamburg, Germany) with children in underwear and barefoot; boys’ body mass (kg), total fat (kg), and total lean mass without bone (kg) determined from a total-body scan using DXA with children in a fasting state; body mass index (BMI) calculated as body mass in kilograms divided by height (in meters) squared.

Energy and calcium intake calculated from a semi-quantitative Food Frequency Questionnaire, assessing regular intake of a wide of typical Portuguese foods.

Maturity estimated as the years distance positive or negative from the age of peak height velocity using sex-specific prediction equations [11].

Regression Analysis - BMD

Regression Analysis – BMD RATIOS

Conclusions
BPAQ was a significant positive predictor for all BMD variables (p<0.05) except TR BMD in girls and FN BMDs in boys (p>0.05).

At least one geometric variable was significant in the estimated models for the BMD ratios: in girls, the IAD was a positive predictor of TRBF (p<0.001) and ALA was a negative predictor of FN/PP, in boys, the IAD was a positive predictor of FN/PP (p<0.01) and MLA(p<0.05); also in boys, ALA was a negative predictor of the RM/SL (p<0.001).

The interaction of IAD/ALA predicted FN/SL positively in girls and negatively in boys (p=0.01).

The IAD and the ALA, as indicators of the main lever arms of the biomechanics of the hip, may play a role in the relative mineralization of the proximal femur in peripubertal boys and girls as was theoretically expected.

However unlike total lean body mass and PA, the same geometric variables don’t seem to influence the absolute BMD levels at the proximal femur neck and trochanter.

Further research is needed to better understand the effects of geometric variations on the relative mineralization of the proximal femur regions including the development of a specific biomechanical model to simulate the vector forces exerted on these regions.

References