Factors influencing calcaneus quantitative ultrasound measurements in an urban population

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Abstract

Objective
To estimate the effect of demographic, social, behavioural and anthropometric factors on quantitative ultrasound (QUS) parameters in an urban population.

Methods
Cross-sectional evaluation of consecutive subjects selected as part of the EPIPorto study, Portugal. Information was obtained on demographic, social, clinical and behavioural characteristics using a standard protocol. Calcaneus QUS parameters (Broadband Ultrasound Attenuation – BUA, and Speed of Sound – SOS) were obtained for men and women, stratified by age group. Comparisons according to exposure levels were made using the Kruskal-Wallis test and the multivariate effect on QUS parameters was estimated by linear regression.

Results
1482 consecutive subjects (1010 females and 472 males), aged from 18 to 92 years. Higher levels of QUS parameters were found in the younger groups and progressive decrease with age were reported. Men showed higher values as compared to women in all parameters and differences between them increased with age. Differences were significant for BUA after the age of 39 and for SOS after the age of 59. In women, the multivariate model showed that age, body mass index (BMI) and smoking status were independent predictors of BUA and SOS. In men, age, BMI and calcium intake were significantly associated with BUA and SOS.

Conclusion
The reference values in our Portuguese population are similar to others obtained in Southern European countries. In the Portuguese population, QUS parameters have age, sex and BMI as its major determinants. In addition, BUA and SOS may reflect specific bone characteristics influenced by a different set of independent determinants.

Key words
Calcaneus quantitative ultrasound, reference values, osteoporosis, Portugal, risk factors.

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Introduction

Osteoporosis (OP) is a systemic skeletal disease characterised by low bone mass and micro-architectural deterioration, predisposing to an increased fracture risk (1). In the absence of non-invasive methods to measure bone quality, the diagnosis of OP is based on low bone mineral density (BMD) measured by dual x-ray absorptiometry (DEXA) (2). However, there is only a moderate correlation between BMD and bone strength. The recognition that new methods for assessment of bone quality are needed has motivated the development of complementary techniques to DXA. The propagation of ultrasounds (US) through bone is dependent on bone mass, bone structure and bone material properties. The quantitative measurement by ultrasounds (QUS) can capture indirect information from bone quality. QUS is a portable, non invasive method for the evaluation of peripheral bones and does not use radiation (3). The localization usually chosen is the calcaneus, a predominantly trabecular bone (> 90%) with parallel surface trabeculae and located in an anatomic region easy to position and scan (4).

In Portugal, as in other countries, the use of QUS of the calcaneus has quickly spread. Reference values for QUS are available for several populations (5-7), and we have recently determined the precision, accuracy and normal values for QUS in the Portuguese population (8). Although risk factors for low BMD are well known (9, 10) few data are available about the factors that influence QUS parameters (11, 12).

The objective of this study was to estimate the effect of demographic, social, behavioural and anthropometric factors on QUS parameters, in a Portuguese population.

Material and methods

A cross-sectional evaluation was made of non-institutionalised Caucasian adults, selected as part of the EPIPorto study, a health and nutrition survey of a representative sample of the inhabitants of Porto, Portugal (13). Participants were selected by random digit dialling using households as the sampling frame. Residences were sampled, and in each residence a single adult was selected by simple random sampling. The selected person was invited to visit the Department and an appointment was scheduled. The proportion of participation was 70%. Refusals were not replaced and participants did not differ significantly from non-participants in age, gender, education and in selected cardiovascular risk factors (14). The age and gender distribution in the EPI-Porto cohort is overall similar to the last census results for the city of Porto, though women over 74 years-old were comparatively underrepresented in our sample. The study was approved by the Ethics Committee of São João Hospital and all the participants gave written informed consent. A questionnaire for the characterization of demographic, social, clinical and behavioural data was completed by a trained interviewer (13). For each subject, socio-demographic, anthropometric and lifestyle variables were collected (sex, age, education, height, body mass index (BMI), alcohol intake, smoking status, physical activity), as well as gynaecological and obstetric history in women. Total caloric, calcium and vitamin D intakes were assessed by using a semi-quantitative food frequency questionnaire, which was developed for use in the Portuguese adult population and was previously validated in this population (15). The questionnaire comprises 86 food or food group items. Frequency of consumption is recorded as a categorical variable with nine pre-specified categories from “never or less than once per month” to “six or more times per day”. Pre-specified portion sizes were allocated to each food item. Dietary intake was estimated by multiplying the frequency of intake for any given item by its respective portion size, in grams, and by a seasonal variation factor for foods consumed only in some seasons. The Food Processor Plus® version SQL (ESHA Research, Salem, Oregon) was used to convert food intakes from the questionnaire to nutrient intakes. This database was supplemented with nutritional composition of Portuguese foods and recipes, using data from Portuguese food composition databases (16, 17) and from national and international...
Table I. BUA, SOS, QUI and EBMD values for women (above) and men (below), stratified by age. *P*-values refer to the non-parametric comparison of each ultrasound parameters across age-groups, at a 0.05 significance level.

<table>
<thead>
<tr>
<th>Age</th>
<th>N (%)</th>
<th>BUA Mean (SD)</th>
<th>SOS Mean (SD)</th>
<th>QUI Mean (SD)</th>
<th>EBMD Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤29</td>
<td>116 (11.5)</td>
<td>77 (20)</td>
<td>1564 (35)</td>
<td>102 (21)</td>
<td>0.571 (0.135)</td>
</tr>
<tr>
<td>30 - 39</td>
<td>149 (14.8)</td>
<td>76 (21)</td>
<td>1558 (35)</td>
<td>99 (21)</td>
<td>0.550 (0.133)</td>
</tr>
<tr>
<td>40 - 49</td>
<td>206 (20.4)</td>
<td>71 (15)</td>
<td>1557 (28)</td>
<td>96 (17)</td>
<td>0.536 (0.106)</td>
</tr>
<tr>
<td>50 - 59</td>
<td>222 (22.0)</td>
<td>67 (17)</td>
<td>1548 (27)</td>
<td>91 (17)</td>
<td>0.502 (0.107)</td>
</tr>
<tr>
<td>60 - 69</td>
<td>165 (16.3)</td>
<td>60 (16)</td>
<td>1539 (28)</td>
<td>84 (17)</td>
<td>0.458 (0.107)</td>
</tr>
<tr>
<td>≥70</td>
<td>152 (15.0)</td>
<td>55 (16)</td>
<td>1525 (24)</td>
<td>76 (16)</td>
<td>0.411 (0.100)</td>
</tr>
<tr>
<td>Total</td>
<td>1010 (100)</td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤29</td>
<td>65 (13.8)</td>
<td>81 (23)</td>
<td>1569 (34)</td>
<td>105 (23)</td>
<td>0.592 (0.142)</td>
</tr>
<tr>
<td>30 - 39</td>
<td>77 (16.3)</td>
<td>79 (20)</td>
<td>1558 (33)</td>
<td>100 (21)</td>
<td>0.560 (0.130)</td>
</tr>
<tr>
<td>40 - 49</td>
<td>90 (19.1)</td>
<td>78 (18)</td>
<td>1559 (31)</td>
<td>100 (19)</td>
<td>0.558 (0.121)</td>
</tr>
<tr>
<td>50 - 59</td>
<td>85 (18.0)</td>
<td>73 (15)</td>
<td>1552 (27)</td>
<td>95 (17)</td>
<td>0.529 (0.105)</td>
</tr>
<tr>
<td>60 - 69</td>
<td>79 (16.7)</td>
<td>71 (18)</td>
<td>1545 (26)</td>
<td>91 (17)</td>
<td>0.504 (0.110)</td>
</tr>
<tr>
<td>≥70</td>
<td>76 (16.1)</td>
<td>72 (17)</td>
<td>1547 (26)</td>
<td>93 (17)</td>
<td>0.514 (0.107)</td>
</tr>
<tr>
<td>Total</td>
<td>472 (100)</td>
<td>p = 0.064</td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.002</td>
<td>p &lt; 0.002</td>
</tr>
</tbody>
</table>

BUA: broad ultrasound attenuation; SOS: speed of sound; QUI: quantitative ultrasound index; EBMD: estimated bone mineral density.
BMI and calcium intake were significant BUA and SOS determinants. SOS was also significantly associated with total caloric intake (regression coefficient: 0.01, 95% CI: 0.00-0.01). Physical activity, vitamin D and alcohol intake, Beck depression inventory and SF-36 were not significantly correlated with male QUS parameters (results not shown).

**Discussion**

The role of QUS in OP assessment is still debatable but it has already been proved to be a useful tool for fracture risk assessment (27-29). Moreover, QUS parameters might be particularly useful for screening for patients with a high risk for osteoporosis associated fractures secondary to inflammatory rheumatic diseases (30).

The aims of our study were to estimate the effect of demographic, social, behavioural and anthropometric factors on QUS parameters in a representative sample of urban Portuguese adults. Our data depicted, for both sexes, a decrease of QUS parameters values with increasing age, although this reduction started earlier and was greater in women.

**Table II.** Regression coefficients (95% confidence intervals) for the multivariate model for BUA and SOS in both sexes regarding anthropometric, social and behavioural factors.

<table>
<thead>
<tr>
<th>Variables</th>
<th>BUA Univariate</th>
<th>BUA Multivariate*</th>
<th>SOS Univariate</th>
<th>SOS Multivariate*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (per year)</td>
<td>-0.20 (-0.30, 0.10)</td>
<td>-0.22 (-0.33, -0.10)</td>
<td>-0.48 (-0.55, -0.42)</td>
<td>-0.55 (-0.71, -0.39)</td>
</tr>
<tr>
<td>Education (per year)</td>
<td>0.30 (0.04, 0.57)</td>
<td>0.03 (-0.38, 0.43)</td>
<td>0.88 (0.67, 1.09)</td>
<td>0.15 (-0.20, 0.50)</td>
</tr>
<tr>
<td>BMI (per kg/m²)</td>
<td>0.72 (0.30, 1.14)</td>
<td>1.04 (0.61, 1.47)</td>
<td>-0.28 (-0.51, -0.04)</td>
<td>0.36 (0.04, 0.69)</td>
</tr>
<tr>
<td>Calcium intake (per mg/day)</td>
<td>0.01 (0.00, 0.01)</td>
<td>0.01 (0.00, 0.01)</td>
<td>0.00 (-0.01, 0.00)</td>
<td>0.00 (-0.01, 0.00)</td>
</tr>
<tr>
<td>Vitamin D intake (per μg/day)</td>
<td>0.16 (-0.51, 0.84)</td>
<td>-0.48 (-1.18, 0.23)</td>
<td>-0.12 (-0.57, 0.34)</td>
<td>0.03 (-0.57, 0.64)</td>
</tr>
<tr>
<td>Ethanol intake (per g/day)</td>
<td>0.00 (-0.07, 0.06)</td>
<td>0.01 (-0.05, 0.07)</td>
<td>-0.12 (-0.25, -0.02)</td>
<td>-0.02 (-0.13, 0.09)</td>
</tr>
<tr>
<td>Smoker (ever vs. never)</td>
<td>0.45 (-3.34, 4.24)</td>
<td>-0.86 (-4.52, 2.80)</td>
<td>4.41 (1.81, 7.00)</td>
<td>-6.32 (-11.59, -1.04)</td>
</tr>
<tr>
<td>Reproductive period (per year)</td>
<td>0.05 (-0.21, 0.30)</td>
<td>0.11 (-0.15, 0.37)</td>
<td>0.29 (-0.12, 0.70)</td>
<td>0.44 (0.04, 0.85)</td>
</tr>
</tbody>
</table>

*p multivariate coefficients were adjusted for all variables in the table. BUA: broadband ultrasound attenuation; SOS: speed of sound.
than in men. These findings in the Portuguese population were similar to others previously published in Southern European countries (5, 6).

There are few published studies on factors that potentially influence QUS parameters (7, 11, 12, 31, 32). In our work, the multivariate model showed that age, BMI and smoking status in women were independent predictors of BUAl and SOS. Additionally, the duration of the reproductive period was associated with SOS. In men, age, BMI and calcium intake were found to be significantly associated with BUAl and SOS. Total caloric intake exerted a significant effect only in some QUS parameters. Factors such as education level, physical activity, vitamin D and alcohol intake, Beck depression inventory and SF-36 did not present any association with QUS values. The results here described are in accordance with other previous studies such as the ES-OP study, performed in Italian men and women (32). The effect of age and BMI on QUS parameters was expected as they are major determinants of bone mass (1). Smoking status is also a well known risk factor for OP and the reason for a lack of effect of this variable on QUS parameters in man is not clear. However, in accordance with this, Kaji et al. (33), using peripheral quantitative computed tomography, found high correlation between smoking habits and volumetric bone mineral density in women, although in man, this correlation was not observed. On the other hand, our findings might also reflect the decreasing smoking habits as opposed to the increasing smoking habits in women (34).

On the contrary, calcium intake did not influence QUS parameters in women, which might be explained by a more homogeneous calcium intake pattern in women, due to increase awareness of OP (34).

In our population, QUS parameters have age, sex and BMI as their major determinants. In addition, BUAl and SOS may reflect specific bone characteristics influenced by a different set of independent determinants.

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