Factors associated with bone mineral density in adults: a cross-sectional population-based study

ABSTRACT
Objective: This study aimed to analyze the association between lumbar spine, femoral neck, total hip bone mineral density (biophysical bone health assessment parameter), and sociodemographic, anthropometric, behavioral, and health condition factors in Brazilian adults. Method: This is a cross-sectional, population-based study performed with individuals of both genders, aged between 20 and 59 (n=701). The dependent variables were evaluated by Dual Energy X-ray Absorptiometry. The independent variables were evaluated through a questionnaire, anthropometric evaluation and blood collection. The association between bone mineral density and the independent variables was evaluated by linear regression analysis. All analyses were stratified by gender. Results: Men presented higher bone mineral density than women. Bone mineral density was inversely associated with age range and directly associated with nutritional status in both genders and in the three bone sites analyzed. In addition, 25 Hydroxyvitamin D deficient status among men and contraceptive use among women were associated with lower bone mineral density, and a significant association was only found with lumbar spine bone mineral density in women. Conclusion: The factors associated with bone health among men were age, skin color, nutritional status, and vitamin D status. For women, the associated factors with bone health were age, skin color, nutritional status and contraceptive use.

DESCRIPTORS
Bone Density; Risk Factors; Adult Health; Epidemiologic Studies.

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INTRODUCTION

The world has undergone great socioeconomic, demographic and epidemiological changes in the last decades, which have caused (among other situations) a gradual increase in life expectancy. Brazil is not different from other countries, and the older adult population has experienced a marked increase since 2010; this increase in life expectancy has been higher for men\(^{15}\) in such a way that if it remains so, it is estimated that more than 35% of the population will be older adults by 2070. As a result of this phenomenon of population aging, a significant increase may occur in the prevalence of chronic non-communicable diseases, with an emphasis on those related to low bone mineral density (BMD) (osteopenia and osteoporosis), as well as its consequences such as the risk of falls and fractures. It is estimated that the risk of fractures due to low bone mass levels from the age of 40 is 25.6% in women and 15.5% in men, with hip, distal radius and vertebral (compression fracture) becoming more common, along with a higher incidence in older postmenopausal white women\(^{4,6}\). On the other hand, there has been a significant increase in hip fractures in men, with about 30% of total hip fractures occurring in this group and half of them before the age of 80 years\(^{3}\).

There is a large variation between the results of studies on the prevalence of osteoporosis in Brazil, as they use different methods to evaluate the presence of osteoporosis such as self-report and bone densitometry examination\(^{3,4-10}\). Furthermore, most of the studies show no population-based data and are essentially performed with postmenopausal women\(^{5,6}\). However, a high incidence of osteoporosis has been observed in men in the last 20 years\(^{3}\). Thus, it is estimated that the general prevalence of osteoporosis in Brazilians ranges from 15% to 30% in women\(^{7}\), and 2 to 8% in men\(^{3}\).

In view of this epidemiological situation, the identification of factors associated with bone health is fundamental to combat the progression of osteometabolic diseases. In this sense, studies have shown that age and gender\(^{5,6,8,10}\), use of medications and hormones\(^{5,11-12}\), body composition\(^{6,10}\), behavioral and environmental aspects\(^{12-14}\), and food consumption\(^{15}\) are factors associated with bone metabolism. However, few studies have been conducted with adults of both genders\(^{4,16}\), and the existing studies assess risk factors in isolation\(^{5,15}\). Most studies are with older individuals and postmenopausal women. Studies evaluating bone mineral density in adults are scarce.

Therefore, identification of possible factors associated with the compromise of bone health in adults of both genders is important to understand the process of bone deterioration due to aging. This diagnosis has also become important for men because of the increased incidence of osteoporosis in these individuals. Furthermore, preventive actions may be planned from the identification of such factors in order to mitigate the consequences of declining bone health and public health expenditures. Therefore, the objective of the present study was to evaluate the factors associated with bone mineral density of the lumbar spine (BMD-LS), femoral neck (BMD-FN) and total femur (BMD-TF) in adults.
(divided into three categories according to the weekly consumption of alcoholic beverages, being 0, 1-7 and >8 drinks); and smoking (non-smokers, smokers and ex-smokers).

The second stage consisted of evaluation of anthropometric measures, physical activity level (PAL), and blood collection, all performed by trained professionals in the laboratory. Measurements of total body mass (Kg) and height (cm) were obtained according to recommendations in the literature in order to calculate body mass index (BMI), which was calculated using the formula: weight (kg)/[height (m)]² (18), and categorized into: eutrophic (<24.9 kg/m²), overweight (25.0 kg/m² to 29.9 kg/m²), and obese (>30.0 kg/m²) (18).

PAL was determined through the International Physical Activity Questionnaire (IPAQ), version 6, long format, validated for the Brazilian population (19). PAL score was calculated by summing the time spent doing physical activity (PA) of moderate intensity (including walking) and vigorous intensity, which was obtained by the time spent doing vigorous PA multiplied by two ([PAL= moderate PA + (vigorous PA)x2]). The PAL of the individuals evaluated was subsequently calculated according to Domain 4 in the IPAQ, referring to recreational, sports, exercise and leisure physical activities. PAL was categorized according to the time of PA performed in the week prior to applying the questionnaire into: irregularly active (IA) (<150min/week), and physically active (PA) (≥150min/week) (19).

Blood collection was performed to determine the 25 Hydroxyvitamin D [25(OH)D] status, which was evaluated by chemiluminescence, using the ARCHITECT 25(OH)D kit, on the ARCHITECT/ABBOTT instrument. Blood samples were collected by peripheral endovenous puncture using the disposable vacuum system after 12 hours of fasting between seven and ten o’clock in the morning. The 25(OH)D status was determined according to the following reference values: sufficient (≥30.0 ng/ml), insufficient (21.0 ng/ml to 29.9 ng/ml), and deficient (≤20.9 ng/ml) (20). Although there is a new proposal for the 25(OH)D reference intervals (95% CI). Differences between the groups were verified through the comparison of the 95% CIs. The normality of the dependent variable was tested using the Shapiro-Wilk test and histograms. The association between BMD and the independent variables was evaluated by simple and multiple linear regression analysis. Variables with p-value < 0.25 in the simple regression analysis were tested in the multiple models. Only the variables with p-value ≤0.05 were maintained in the final model. The significance level adopted for all analyses was 5% (α=0.05), and stratified by gender.

ETHICAL ASPECTS

This study is part of a larger research project, approved by the Ethics Committee on Human Research of the Universidade Federal de Viçosa (No. 02/2013/CEP/12.07.2013). All volunteers who agreed to participate signed the informed consent form in accordance with the National Health Council’s Regulatory Guidelines for Research Involving Human Beings, Ministry of Health (21). The return was sent with the results to all study participants. Those who presented alterations in one of the behavioral, biochemical and/or anthropometric variables, or in relation to bone health were asked to look for qualified professionals or the health unit closest to their residence, and were informed of their location.

RESULTS

From the total of 701 individuals included in the study, 50.3% were female, 26.2% were between 30 and 39 years old, 61.4% declared themselves to be non-white, 56.5% belonged to the intermediate consumption class, and 42.8% had high school education, with more than 12 completed years of study. The sample presented 50.3% eutrophic individuals, 72.6% IA individuals, 65.1% non-smokers, and 46.0% did not consume alcoholic beverages. Regarding the 25(OH)D status, 49.0% were classified as having sufficient levels. In relation to women, 64.7% were non-menopausal, 96.4% did not use hormone replacement, and 81.0% used contraceptives. Men and women were similar in relation to the distribution of study variables, except that men reported higher consumption of alcoholic beverages and women had a higher frequency of 25(OH)D deficiency.

Table 1 shows the mean values of BMD-LS, BMD-FN, and BMD-TH according to the study variables in men. BMD values were significantly higher among obese than eutrophic individuals for all evaluated bone sites. In addition, mean BMD-LS and BMD-TH were higher in the overweight compared to the eutrophic individuals. On the other hand, significantly lower bone mass values only for the BMD-FN site were observed among older individuals (40–49 and 50–59 years old) than among younger ones (20–29 years old), and among the less educated (0–4 years of schooling) compared to those with higher education (9–11 and ≥12 years). Men with 25(OH)D deficiency had...
Factors associated with bone mineral density in adults: a cross-sectional population-based study

Bone mass means which were significantly lower than those with sufficiency, regardless of the site evaluated. In addition, individuals with 25(OH)D insufficiency had a higher mean of BMD-TH than those with deficiency (Table 1).

Table 1 – Mean values, BMD confidence intervals according to study variables among men – Viçosa, MG, Brazil, 2012-2014. (n=701)

| Variables                  | BMD-LS (g/cm²) |       | BMD-FN (g/cm²) |       | BMD-TH (g/cm²) |       |
|----------------------------|----------------|-------|----------------|-------|----------------|-------|
|                            | Mean           | CI 95%| Mean           | CI 95%| Mean           | CI 95%|
| Overall                    | 1.204(1.181-1.227) | 1.094(1.075-1.113) | 1.093(1.079-1.106) |
| Age range (years)          |                |       |                |       |                |       |
| 20-29                      | 1.220          | 1.194-1.246 | 1.154* | 1.131-1.176 | 1.120 | 1.098-1.143 |
| 30-39                      | 1.234          | 1.193-1.275 | 1.107* | 1.075-1.140 | 1.086 | 1.055-1.118 |
| 40-49                      | 1.182          | 1.126-1.239 | 1.073* | 1.039-1.106 | 1.081 | 1.049-1.113 |
| 50-59                      | 1.168          | 1.116-1.221 | 1.025* | 0.982-1.068 | 1.076 | 1.034-1.119 |
| Skin Color                 |                |       |                |       |                |       |
| White                      | 1.174          | 1.137-1.211 | 1.074 | 1.046-1.102 | 1.073 | 1.051-1.095 |
| Non-white                  | 1.226          | 1.197-1.255 | 1.109 | 1.083-1.136 | 1.107 | 1.083-1.130 |
| Consumption Class          |                |       |                |       |                |       |
| High                       | 1.211          | 1.175-1.248 | 1.097 | 1.061-1.134 | 1.098 | 1.072-1.124 |
| Intermediate               | 1.201          | 1.170-1.231 | 1.094 | 1.074-1.113 | 1.090 | 1.073-1.106 |
| Low                        | 1.194          | 1.123-1.264 | 1.089 | 1.031-1.147 | 1.102 | 1.043-1.162 |
| Education (years)          |                |       |                |       |                |       |
| 0-4                        | 1.195          | 1.170-1.220 | 1.041* | 0.998-1.085 | 1.095 | 1.064-1.126 |
| 5-8                        | 1.171          | 1.103-1.239 | 1.072 | 1.023-1.121 | 1.077 | 1.037-1.118 |
| 9-11                       | 1.230          | 1.181-1.279 | 1.127* | 1.089-1.165 | 1.127 | 1.093-1.161 |
| ≥ 12                       | 1.207          | 1.172-1.242 | 1.107* | 1.086-1.128 | 1.083 | 1.064-1.102 |
| Nutritional Status         |                |       |                |       |                |       |
| Eutrophic                  | 1.159*         | 1.128-1.191 | 1.070* | 1.040-1.099 | 1.053* | 1.030-1.077 |
| Overweight                 | 1.246*         | 1.209-1.283 | 1.102 | 1.068-1.137 | 1.111* | 1.085-1.137 |
| Obese                      | 1.244*         | 1.197-1.290 | 1.163* | 1.110-1.215 | 1.183* | 1.142-1.225 |
| PAL                        |                |       |                |       |                |       |
| IA                         | 1.192          | 1.170-1.215 | 1.080 | 1.059-1.100 | 1.086 | 1.070-1.103 |
| PA                         | 1.233          | 1.176-1.290 | 1.135 | 1.098-1.172 | 1.111 | 1.076-1.146 |
| Smoking                    |                |       |                |       |                |       |
| Non-smoker                 | 1.214          | 1.184-1.244 | 1.107 | 1.089-1.124 | 1.089 | 1.074-1.104 |
| Smoker                     | 1.178          | 1.138-1.219 | 1.084 | 1.041-1.128 | 1.096 | 1.054-1.138 |
| Ex-smoker                  | 1.192          | 1.150-1.235 | 1.068 | 1.032-1.105 | 1.101 | 1.073-1.128 |
| Alcoholism (drinks/week)   |                |       |                |       |                |       |
| 0                          | 1.200          | 1.160-1.240 | 1.072 | 1.023-1.121 | 1.079 | 1.043-1.115 |
| 1-7                        | 1.203          | 1.170-1.235 | 1.104 | 1.080-1.128 | 1.088 | 1.065-1.111 |
| 8 or more                  | 1.211          | 1.173-1.249 | 1.104 | 1.074-1.134 | 1.120 | 1.097-1.144 |
| 25(OH)D                    |                |       |                |       |                |       |
| Sufficient                 | 1.219*         | 1.195-1.243 | 1.109* | 1.086-1.132 | 1.106* | 1.090-1.122 |
| Insufficient               | 1.205          | 1.163-1.247 | 1.090 | 1.050-1.130 | 1.095 | 1.061-1.128 |
| Deficient                  | 1.104*         | 1.038-1.170 | 1.020* | 0.965-1.074 | 1.002* | 0.945-1.059 |

Table 2 shows the mean values of BMD according to the study variables in the three evaluated bone sites among women. Significantly lower values of BMD-LS and BMD-FN were observed among older women (50-59 years old) compared with younger women (20-29 and 30-39 years old). Regarding nutritional status, obese women also presented significantly higher mean of BMD-LS and DMO-FN than those with overweight and eutrophic. Finally, higher bone mass was identified in the BMD-LS and BMD-FN sites among those non-menopausal and who did not use contraceptives, respectively. When comparing mean BMD between genders, men presented significantly higher values than women for all evaluated bone sites (Table 1 and 2).

Tables 3 and 4 show the gross and adjusted associations of the independent variables which remained in the final model with BMD according to gender. The variables age range, nutritional status, and 25(OH)D for men were significantly associated with BMD in all evaluated bone sites. In addition, race/color was also associated with BMD, however, only in the BMD-LS and DMO-FN bone sites. In the adjusted models we identified that BMD is lower in older individuals, in those who are overweight and obese, non-white, and among those with deficient levels of 25(OH)D (Table 3). We also identified variations in the final models in relation to the evaluated bone sites for women. The variables age range and nutritional status were significantly associated with BMD, regardless of the bone site evaluated, with lower bone mass among older individuals and among eutrophic individuals. Higher bone mass was found among non-white compared to white patients in the BMD-LS and BMD-FN bone sites. Finally, an association was found between using contraceptives and lower BMD-LS (Table 4).
Table 2 – Mean values and confidence intervals (95% CI) of lumbar spine and femur BMD according to study variables among women – Viçosa, MG, Brazil, 2012-2014. (n=701)

| Variables                          | BMD-LS (g/cm²) |         | BMD-FN (g/cm²) |         | BMD-TH (g/cm²) |         |
|------------------------------------|----------------|---------|----------------|---------|----------------|---------|
| Overall                            | 1.151 (1.131-1.171) | 0.991 (0.974-1.007) | 0.999 (0.981-1.017) |         |         |         |
| Age range (years)                  |                |         |                |         |                |         |
| 20-29                              | 1.186 a         | 1.161-1.210 | 1.032 a         | 1.009-1.054 | 1.019 | 0.996-1.042 |
| 30-39                              | 1.200 b         | 1.159-1.241 | 1.031 b         | 0.996-1.065 | 1.010 | 0.970-1.051 |
| 40-49                              | 1.184 c         | 1.156-1.212 | 0.987         | 0.958-1.016 | 1.007 | 0.973-1.040 |
| 50-59                              | 1.055 a,b,c     | 1.005-1.104 | 0.926 a,b     | 0.889-0.963 | 0.967 | 0.934-1.001 |
| Skin Color                         |                |         |                |         |                |         |
| White                              | 1.115           | 1.085-1.144 | 0.965         | 0.939-0.992 | 0.975 | 0.952-0.998 |
| Non-white                          | 1.170           | 1.142-1.197 | 1.004         | 0.982-1.026 | 1.013 | 0.986-1.039 |
| Consumption Class                  |                |         |                |         |                |         |
| High                               | 1.156           | 1.120-1.191 | 0.980         | 0.955-1.006 | 0.980 | 0.945-1.014 |
| Intermediate                       | 1.155           | 1.131-1.179 | 0.993         | 0.971-1.015 | 1.003 | 0.982-1.023 |
| Low                                | 1.121           | 1.046-1.195 | 0.997         | 0.942-1.053 | 1.019 | 0.957-1.081 |
| Education (years)                  |                |         |                |         |                |         |
| 0-4                                | 1.116           | 1.047-1.186 | 0.963         | 0.920-1.006 | 0.995 | 0.951-1.039 |
| 5-8                                | 1.159           | 1.111-1.207 | 1.018         | 0.977-1.059 | 1.028 | 0.990-1.066 |
| 9-11                               | 1.145           | 1.109-1.182 | 0.991         | 0.961-1.022 | 0.992 | 0.958-1.025 |
| ≥ 12                               | 1.172           | 1.151-1.194 | 0.994         | 0.971-1.017 | 0.993 | 0.971-1.016 |
| Nutritional Status                 |                |         |                |         |                |         |
| Eutrophic                          | 1.136           | 1.113-1.160 | 0.972 a         | 0.949-0.994 | 0.966 a | 0.942-0.990 |
| Overweight                         | 1.157           | 1.120-1.193 | 0.981 b         | 0.957-1.010 | 0.999 b | 0.973-1.025 |
| Obese                              | 1.181           | 1.145-1.217 | 1.050 a,b     | 1.012-1.089 | 1.087 a,b | 1.060-1.114 |
| PAL                                |                |         |                |         |                |         |
| IA                                 | 1.148           | 1.121-1.175 | 0.998         | 0.976-1.019 | 1.001 | 0.979-1.024 |
| PA                                 | 1.158           | 1.126-1.190 | 0.972         | 0.942-1.003 | 0.994 | 0.964-1.024 |
| Smoking                            |                |         |                |         |                |         |
| Non-smoker                         | 1.163           | 1.136-1.190 | 1.000         | 0.977-1.022 | 1.003 | 0.982-1.024 |
| Smoker                             | 1.115           | 1.058-1.172 | 0.968         | 0.929-1.007 | 0.979 | 0.942-1.015 |
| Ex-smoker                          | 1.130           | 1.096-1.163 | 0.972         | 0.938-1.006 | 0.997 | 0.958-1.036 |
| Alcoholism (drinks/week)           |                |         |                |         |                |         |
| 0                                  | 1.141           | 1.117-1.165 | 0.985         | 0.964-1.006 | 1.000 | 0.982-1.018 |
| 1-7                                | 1.162           | 1.125-1.200 | 0.993         | 0.967-1.019 | 0.990 | 0.959-1.020 |
| 8 or more                          | 1.206           | 1.160-1.252 | 1.053         | 0.989-1.116 | 1.065 | 1.016-1.115 |
| Menopause                          |                |         |                |         |                |         |
| No                                 | 1.189 a         | 1.163-1.215 | 1.016         | 0.955-1.037 | 1.011 | 0.987-1.035 |
| Yes                                | 1.081 a         | 1.034-1.128 | 0.942         | 0.909-0.975 | 0.976 | 0.945-1.008 |
| Hormone Replacement Therapy        |                |         |                |         |                |         |
| No                                 | 1.152           | 1.132-1.171 | 0.992         | 0.975-1.010 | 1.000 | 0.981-1.019 |
| Yes                                | 1.130           | 1.028-1.233 | 0.943         | 0.887-0.998 | 0.982 | 0.924-1.041 |
| Contraceptive                      |                |         |                |         |                |         |
| No                                 | 1.189           | 1.164-1.214 | 1.031 a         | 1.005-1.060 | 1.020 | 0.991-1.048 |
| Yes                                | 1.140           | 1.111-1.168 | 0.976 a         | 0.954-0.998 | 0.966 | 0.974-1.017 |
| 25(OH)D                            |                |         |                |         |                |         |
| Sufficient                         | 1.168           | 1.138-1.198 a | 0.991 a     | 0.969-1.013 | 0.989 | 0.961-1.017 |
| Insufficient                       | 1.136           | 1.101-1.171 | 0.976         | 0.951-1.000 | 0.966 | 0.970-1.021 |
| Deficient                          | 1.145           | 1.098-1.193 a | 1.022 a     | 0.974-1.069 | 1.032 | 0.993-1.071 |

BMD-LS: lumbar spine mineral density; BMD-FN: femoral neck mineral density; BMD-TH: total hip mineral density; PAL: physical activity level; IA: irregularly active; PA: physically active; 25(OH)D:25-Hydroxyvitamin D. Same letters indicate statistically significant differences.
Factors associated with bone mineral density in adults: a cross-sectional population-based study

Table 3 – Simple, multiple linear regression, confidence intervals, p-value for BMD among men – Viçosa, MG, Brazil, 2012-2014. (n=701)

| Variables       | BMD-LS (g/cm²) | BMD-FN (g/cm²) | BMD-TH (g/cm²) |
|-----------------|----------------|----------------|----------------|
|                 | β CI 95%       | β Adj CI 95%   | β CI 95%       | β Adj CI 95%   | β CI 95%       | β Adj CI 95%   |
| **Age Range (years)** |                 |                 |                 |                 |                 |                 |
| 20-29           | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       |
| 30-39           | 0.14 -0.03;0.06| 0.06 -0.03;0.05| -0.04 -0.08;0.09| -0.05 -0.08;0.02| 0.03 -0.06;0.01| -0.04 -0.07;0.01|
| 40-49           | -0.03 -0.09;0.02| -0.07 -0.11;0.02| -0.08 -0.12;0.03| -0.10 -0.14;0.06| -0.04 -0.09;0.02| -0.10 -0.09;0.06|
| 50-59           | -0.05 -0.10;0.06| -0.07 -0.12;0.02| -0.12 -0.17;0.07| -0.15 -0.19;0.11| -0.04 -0.09;0.04| -0.15 -0.14;0.11|
| **Skin Color**  |                 |                 |                 |                 |                 |                 |
| White           | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | ---             | ---             |
| Non-White       | 0.05 0.04;0.09| 0.03 0.02;0.07| 0.03 -0.04;0.07| 0.03 0.00;0.06| ---             | ---             |
| **Nutritional Status** |                 |                 |                 |                 |                 |                 |
| Eutrophic       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       |
| Overweight      | 0.08 0.03;0.13| 0.10 0.05;0.14| 0.03 -0.01;0.08| 0.05 0.07;0.10| 0.05 0.01;0.09| 0.06 0.01;0.10|
| Obese           | 0.08 0.03;0.13| 0.10 0.05;0.14| 0.09 0.03;0.15| 0.12 0.07;0.18| 0.13 0.08;0.17| 0.13 0.07;0.19|
| **25(OH)D**     |                 |                 |                 |                 |                 |                 |
| Sufficient      | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       |
| Insufficient    | -0.01 -0.06;0.02| -0.04 -0.06;0.02| -0.01 -0.06;0.02| -0.01 -0.05;0.18| -0.01 -0.04;0.02| -0.01 -0.04;0.02|
| Deficient       | -0.11 -0.18;0.04| -0.09 -0.16;0.05| -0.08 -0.14;0.03| -0.08 -0.01;0.03| -0.01 -0.06;0.04| -0.08 -0.13;0.04|

BMD-LS: bone mineral density of the lumbar spine; BMD-FN: bone mineral density of the femoral neck; BMD-TH: bone mineral density of total hip.
β:  β value for simple linear regression
βAdj: β value adjusted to covariates

Table 4 – Simple, multiple linear regression, confidence intervals, p-value for BMD among women – Viçosa, MG, Brazil, 2012-2014. (n=701)

| Variables       | BMD-LS (g/cm²) | BMD-FN (g/cm²) | BMD-TH (g/cm²) |
|-----------------|----------------|----------------|----------------|
|                 | β CI 95%       | β Adj CI 95%   | β CI 95%       | β Adj CI 95%   | β CI 95%       | β Adj CI 95%   |
| **Age Range (years)** |                 |                 |                 |                 |                 |                 |
| 20-29           | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       |
| 30-39           | 0.14 -0.03;0.06| 0.01 -0.05;0.07| -0.01 -0.03;0.03| -0.01 -0.05;0.01| -0.08 -0.04;0.02| -0.02 -0.06;0.08|
| 40-49           | -0.01 -0.04;0.03| -0.03 -0.08;0.02| -0.04 -0.08;0.03| -0.07 -0.11;0.03| -0.01 -0.05;0.03| -0.04 -0.08;0.03|
| 50-59           | -0.13 -0.19;0.07| -0.16 -0.23;0.10| -0.10 -0.14;0.06| -0.13 -0.17;0.09| -0.05 -0.08;0.01| -0.09 -0.13;0.05|
| **Skin Color**  |                 |                 |                 |                 |                 |                 |
| White           | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | ---             | ---             |
| Non-White       | 0.05 0.01;0.09| 0.04 0.09;0.08| 0.03 0.04;0.07| 0.02 -0.01;0.05| ---             | ---             |
| **Contraceptive** |                 |                 |                 |                 |                 |                 |
| No              | 0.00 ---       | 0.00 ---       | ---             | ---             | ---             | ---             |
| Yes             | 0.04 0.06;0.09| -0.01 -0.06;0.02| ---             | ---             | ---             | ---             |
| **Nutritional Status** |                 |                 |                 |                 |                 |                 |
| Eutrophic       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       | 0.00 ---       |
| Overweight      | 0.02 -0.02;0.06| 0.02 -0.01;0.06| 0.01 -0.02;0.04| 0.03 0.03;0.06| 0.03 -0.09;0.06| 0.04 0.01;0.08|
| Obese           | 0.04 -0.06;0.08| 0.04 0.01;0.07| 0.07 0.03;0.12| 0.10 0.07;0.14| 0.12 0.08;0.15| 0.14 0.10;0.17|

BMD-LS: bone mineral density of the lumbar spine; BMD-FN: bone mineral density of the femoral neck; BMD-TH: bone mineral density of total hip.
β:  β value for simple linear regression
βAdj: β value adjusted to covariates

In addition to the variables present in the final models (Tables 3 and 4), the following variables with p<0.25 were introduced in the simple linear regression: at the BMD-FN site for men, education (p=0.005) and PAL (p=0.017); at the BMD-LS site for women, smoking (p=0.053), alcoholism (p=0.094), and menopause (p=0.027); and at the BMD-FN site for women, menopause (p=0.002), hormone replacement therapy (p=0.098), and contraceptive use (p=0.003). However, these did not remain in the final models, since they were non-significant (p>0.05) in the multiple models.

DISCUSSION

In this study, we identified that men had significantly higher mean BMD values than women. The main variables associated with BMD of the evaluated bone sites in both genders were age range, race/color, and nutritional status. In addition, associations with 25(OH)D status were identified among men, and contraceptive use among women.

Bone health is usually evaluated by biophysical parameters which quantify bone mass (bone mineral content and density). However, BMD is more clinically used since it evaluates specific bone sites in which the osteopenia process begins.

We identified that lower BMD values are associated with high age, which corroborates other studies(5,9). Bone loss in both genders is a consequence of the deleterious effects of aging, because the balance between bone formation and absorption changes and BMD progressively decreases as age increases. There is a peak in bone mass and accumulation of bone tissue up to 30 years, such that men accumulate 25% more BMD than women(22), which contributes to delaying the loss of BMD in men. Then there is a gradual decline which intensifies after menopause for women due to the decrease in estrogen levels.
to a decrease in estrogen, while it occurs for men after 70 years when there is also a decrease in testosterone levels, which delays the consequences of loss of BMD, such as fractures (for example) in relation to women\textsuperscript{8}. Thus, bone metabolism during adulthood should remain balanced, as this will contribute to good bone health and will lower the risk of bone loss as one ages.

Therefore, bone loss is also related to hormonal issues, with sex hormones being one of the main biological agents regulating bone health and responsible for maturation and sexual dimorphism of the skeleton\textsuperscript{22}. However, no differences were observed among women who use or do not use hormone replacement therapy in our study, since less than 5% used it because it is a younger population, and it is known that hormone replacement has been used as a prevention for the decline of bone health during menopause in an attempt to delay the deleterious effects of bone health in women during this period\textsuperscript{12}.

In addition to the issues mentioned above, behavioral aspects have been pointed out as a possible explanation for the differences in bone health between men and women, among which PA and contraceptive use stand out. Although no association between PAL and bone health has been found in this study, it is known that regular PA is considered an important non-pharmacological alternative for bone health maintenance and prevention of osteometabolic diseases. Furthermore, although there is a consensus in the literature regarding these and other benefits related to PA, there is still a high prevalence of inactive people in Brazil, with important differences between genders. A study carried out with Brazilian adults showed that 62.4% are insufficiently active, with women (70.1%) being more sedentary than men (53.3%), and this situation worsens with aging\textsuperscript{23}. The non-association between PAL and bone health in this study is attributed to the instrument used for the assessment of PAL, since it has important limitations in that it does not consider the history and type of exercise performed, only frequency and intensity at the current moment\textsuperscript{20}.

With respect to behavioral factors in addition to PA, there is strong evidence that excessive alcohol consumption and smoking has a negative influence on bone metabolism\textsuperscript{13-14}. Regarding smoking, we found that smokers and former smokers in our study had lower BMD means than non-smokers, although these differences were not significant. The literature indicates that nicotine directly interferes in the amount of calcium absorbed by the skeleton, on the activity of vitamin D, and consequently of parathyroid hormone, in addition to inducing weight loss and physical inactivity, which may not favor the maintenance of bone health\textsuperscript{13-14}. However, the results of the studies on the subject are inconsistent, so there is a need to carry out further investigations which consider other aspects such as the time of exposure to tobacco and the amount of cigarettes consumed\textsuperscript{24}. In turn, the abusive consumption of alcoholic beverages inhibits the activity of vitamin D, parathyroid, androgen and estrogen hormones, and thus affects bone structure maintenance\textsuperscript{15}. Despite this evidence, we did not identify any association between these two behaviors and BMD in our study.

Nutritional status was also identified as a positively associated factor with BMD in both genders, as reported by other studies\textsuperscript{6,10}. According to the authors, this association can be explained by the mechanical pressure that the overloaded body exerts on the skeleton stimulating bone metabolism. However, obesity is considered a serious global public health problem, constituting a risk factor for several diseases such as type II diabetes and cardiovascular diseases\textsuperscript{25}. Furthermore, unlike our findings, being overweight was found to lead to metabolic alterations detrimental to bone health such as insulin resistance and overproduction of the hormones androgen and estrogen, which reduce osteoblast activity\textsuperscript{25}. In addition, excess production of adipokines or leptin levels associated with high intakes of high fat foods contributed to increased intestinal calcium absorption, leading to a reduction in bioavailable calcium for bone remodeling\textsuperscript{26}. Therefore, this association of excess body weight with bone health should be analyzed with great caution, since the harm provided by obesity outweigh the benefits in relation to the activation of bone metabolism.

Another important issue that has been discussed is the association between excess body fat and vitamin D deficiency\textsuperscript{27}. Some authors attribute this association to the nutritional deficiency in obese individuals\textsuperscript{27-29}, or for physiological reasons, as the adipose tissue has bioreceptors which retain 25(OH)D, decreasing the bioavailability of this vitamin\textsuperscript{27}. Although 25(OH)D is not considered a bone biomarker, its adequate levels have been pointed out as a physiological parameter positively associated with bone health\textsuperscript{15,28}. In this sense, we found a positive association between 25(OH)D and BMD for all evaluated bone sites among men. In turn, no relationship was observed among women. It is suggested that this finding can be partially explained by the reference values used for the 25(OH)D status, since it has been shown that women need higher levels of this vitamin to maintain adequate bone activation patterns\textsuperscript{28}. Therefore, there is a need for more detailed studies to evaluate the possible interrelationships between body composition, bone health, and vitamin D status.

Regarding skin color, other studies report that non-white people have higher bone mass when compared to the reference population (caucasian whites)\textsuperscript{28-29}, being in agreement with our findings. The relationship between skin color and BMD is directly related to 25(OH)D status, as there is a variation between the minimum levels for activation of bone metabolism in whites (30ng/ml) and non-whites (20ng/ml), but there is still no consensus in the literature regarding these values\textsuperscript{28-29}. A study performed with black Americans aged from 28 to 48 years found that 50% of the African immigrants evaluated increased the supply of parathyroid hormone and absorption of calcium from the minimum levels of 25(OH)D (<20ng/ml), indicating that these individuals have higher BMD than Caucasians\textsuperscript{29}. This result corroborates other study findings that this 25(OH)D threshold seems to be adequate for the population of African immigrants in the USA\textsuperscript{10}. In addition, non-whites have lower vitamin D concentrations, which is probably due to the increased skin pigmentation which inhibits the
production of cholecalciferol, the precursor of 25(OH)D synthesis\(^{(30)}\). Thus, despite having lower levels of 25(OH)D, black men and women have higher BMD\(^{(30)}\). Although there is evidence that black individuals have denser bones and lower fracture rates than whites, high concentrations of parathyroid hormones resulting from low concentration levels of 25(OH)D may have negative skeletal consequences for black populations\(^{(30)}\). Therefore, although some studies have found an association between race/white skin color and poorer bone health, further studies are needed to assess other intervening factors such as sun exposure, use of sunscreen, metabolism of vitamin D, and other bone biomarkers.

Although this is a cross-sectional study and as such the identified associations cannot be interpreted as a causal relationship, our results contribute to creating prevention strategies for risk factors related to bone health. As previously mentioned, there are few population-based studies on bone health with the adult population and their associated factors, and no studies with such characteristics have been identified in the literature with the Brazilian population. Our results show the importance of bone health evaluation in adults and that identifying factors associated with BMD can contribute to screening individuals with a higher risk of low bone mass who should be a target for preventive measures, mainly for modifiable factors such as overweight and obesity, as well as vitamin D deficiency. Another possible aspect is the fact that this study was developed with a representative sample of the population which enables extrapolating the results to other regions with similar population characteristics. A key strength of this study is the fact that it is population-based, in which factors associated with low bone health were evaluated in individuals of the general population, including men. This is important because the majority of the studies evaluated post-menopausal women, individuals with high ages, and those presenting some specific harm. Thus, this study contributes to existing research conducted up to the present moment. The limitation to the study is that the behavioral factors (PAL, smoking, and alcoholism) were only evaluated at one point of time, given the transversal nature of the research.

**CONCLUSION**

The findings of this study indicate that the main factors associated with low BMD among men were high age, race/white skin, eutrophy, and deficient status of 25(OH)D. In addition to the same relationships observed for men in relation to age range, race/skin color, and nutritional status, we also identified an association with contraceptive use for women.

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