BMC Musculoskeletal Disorders

Research article

Bone mineral density, body mass index and cigarette smoking among Iranian women: implications for prevention

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Abstract

Background: While risk factors of osteoporosis in Western populations have been extensively documented, such a profile has not been well studied in Caucasians of non-European origin. This study was designed to estimate the modifiable distribution and determinants of bone mineral density (BMD) among Iranian women in Australia.

Methods: Ninety women aged 35 years and older completed a questionnaire on socio-demographic and lifestyle factors. BMD was measured at the lumbar spine (LS) and femoral neck (FN) using DXA (GE Lunar, WI, USA), and was expressed in g/cm² as well as T-score.

Results: In multiple regression analysis, advancing age, lower body mass index (BMI), and smoking were independently associated with LS and FN BMD, with the 3 factors collectively accounting for 30% and 38% variance of LS and FN BMD, respectively. LS and FN BMD in smokers was 8% lower than that in non-smokers. Further analysis of interaction between BMI and smoking revealed that the effect of smoking was only observed in the obese group (p = 0.029 for LSBMD and p = 0.007 for FNBMD), but not in the overweight and normal groups. Using T-scores from two bone sites the prevalence of osteoporosis (T-scores ≤ -2.5) was 3.8% and 26.3% in pre-and post-menopausal women, respectively. Among current smokers, the prevalence was higher (31.3%) than that among ex-smokers (28.6%) and non-smokers (7.5%).

Conclusion: These data, for the first time, indicate that apart from advancing age and lower body mass index, cigarette smoking is an important modifiable determinant of bone mineral density in these Caucasians of non-European origin.

Background

Osteoporosis is a common disorder in the elderly population, and represents one of the most significant public health problems in the world, predisposing to fractures with minimal or no antecedent trauma. These fractures are, in turn, associated with increased morbidity [1], reduced quality of life [2], mortality [3], and high health care costs [4].
Bone mineral density (BMD) measurement is considered an effective predictor of fracture risk, such that each standard deviation lower in BMD is associated with at least a 2-fold increase in age adjusted fracture risk [5-7]. Therefore, a useful approach in assessing the importance of aetiological factors for osteoporosis is an investigation of the distribution and determinants of BMD. Although determinants of bone mineral density in Western populations have been extensively studied, such a profile has not been well documented in Caucasians of non-European origin.

Body weight or body mass index (BMI) is known to be positively associated with BMD [8,9]. Lifestyle factors such as low calcium intake, lack of physical activity, and smoking adversely affect bone mineral density and increase the risk of osteoporosis and its related fractures [10]. These factors also play an important role in the determination of peak bone mass and subsequent bone loss during the post-menopausal period. Among the modifiable risk factors of osteoporosis, cigarette smoking is considered one of the deleterious factors because cigarette smokers also have increased risk of fracture [11,12]. Nevertheless, the interactive effect of smoking on BMD has not been well studied. A recent study in a Caucasian population suggested that the effect of smoking was modified by body mass index, such that non-obese smokers had lower BMD than obese-smokers [13]. Iranian women on the average have a relatively high BMI [14,15], and it is not known whether such an interaction effect between smoking and BMI is present in this population.

The present study was designed to examine the modifiable distribution and determinants of bone mineral density among Iranian Australian women.

**Methods**

**Subjects and setting**

This study was designed as a cross-sectional investigation. All women were recruited via a media campaign using newsletters, noticeboards in community halls as well as word of mouth at community centres as part of a larger study to examine osteoporosis prevention in Iranian women. Inclusion criteria for the study were Iranian women and aged 35 years or older. The exclusion criteria were: current or past occurrence of any medical conditions known to affect bone metabolism such as Paget's disease and stroke; current pregnancy; and/or a history of breastfeeding within the last year. Also excluded were women who had been taking any medication affecting bone such as hormones, calcium, and glucocorticoids. In total, 96 women participated in the current study. Six women, who did not meet study's criteria on the basis of diseases or history of taking medications affecting bone, were excluded from the analysis. This study was approved by the University of New South Wales's Human Research Ethics Committee and written informed consent was obtained from each participant.

**Data collection and measurements**

**Socio-demographic characteristics and lifestyle risk factors**

Each woman completed a modified structured questionnaire [16] on socio-demographic and lifestyle risk factors. Income was included to be assessed; however, most participants refused to obtain information about their income level. Reproductive factors such as menopausal status and years since menopause were also provided for each participant. Menopause was defined as previous natural or surgical cessation of menstruation for more than 12 months. Calcium intake was calculated as the sum of current intake of main dairy products (milk, yogurt, and cheese) and was then converted to milligrams of calcium per day. Calcium contents for dairy products were provided from the product information in Australia [17]. Exercise was dichotomized as "yes" for current regular exercising, or "no" for not exercising. Amongst those who exercised, total amount of time spent per week was recorded. Current alcohol use was recorded as "yes" for drinking alcohol (beer, wine and liquor), or "no" for no intake of alcohol. Smoking habits were assessed based on previous and current cigarette smoking. Smoking status was dichotomized as "yes" for smoking, or "no" for never smoking. In addition, amongst those who smoked, dose and duration of smoking was recorded.

**Anthropometric data**

Weight (kg) and height (cm) were measured with light indoor clothing without shoes at the time of bone densitometry measurements. Weight was recorded to the nearest tenth of a kg using an electronic scale and standing height was measured to the nearest centimeter with a stadiometer. Body mass index (BMI) was calculated as body weight in kilograms divided by height in meters squared. According to the World Health Organization (WHO) recommended classification system, overweight and obese individuals were classified as having a BMI between 25 and 29, and equal to or greater than 30 kg/m², respectively [18].

**Bone density measurement**

BMD was measured at the lumbar spine (LS) (L2-L4, anterior-posterior position) and femoral neck (FN) using dual-energy X-ray absorptiometry (DXA) with a Lunar Prodigy densitometer (GE Lunar, WI, U.S.A.). Areal BMD was expressed in g/cm² and in standard deviations from the young normal mean (T-score), based on the Australian Reference Population. The sample of women was grouped into 3 groups based on the WHO recommended criteria: osteoporosis if T-score ≤ -2.5; osteopenia if -2.5 < T-score ≤ -1.0; and normal if T-score > -1.0 [19].
Data analysis
To determine the magnitude of association between the potential risk factors (e.g., menopausal status, height, weight, dairy calcium intake, smoking, exercise, and alcohol use) and osteoporosis risk. Bone mineral density was considered the primary outcome, and was treated as a continuous variable. Individual risk factors were first considered in a simple linear regression analysis to estimate the strength of association between individual risk factor and BMD. In the subsequent analysis, all risk factors were simultaneously considered in a multiple linear regression analysis using the backward elimination algorithms, to screen for independent significant factors. Residual analysis performed to ensure that the usual assumptions of the regression model (i.e. normality, homogeneity and independence) were met. The entry of significance level (p value) was set to 0.10 to arrive at the most robust model.

In further analysis, differences between the pre-menopausal and post-menopausal groups were tested by unpaired t-test for the normally distributed variables, or the Mann-Whitney U test for non-normally distributed variables, and Chi-square test for categorized data. The analysis was performed with the SAS statistical analysis system[20] and SPSS for Windows statistical software [21].

Results
Characteristics of study subjects
The study population consisted of 90 women aged 48.5 ± 8.3 yr (mean age ± SD; range: 35 to 77 yr). Approximately 42 % of the women had education within high school. The majority of the women were married (78%) and performing home duties or not employed (56%). Their average duration of residence in Australia was about 10 years, with 75% of subjects having resided in Australia for at least 5 years. The mean age (SD) at immigration was about 39 ± 9.4 yr (range: 18 to 65 yr). The median (SD) dairy calcium intake in the women was 407 ± 283 mg/day. The Twenty-three women (26%) exercised regularly. Approximately 26% of women smoked cigarettes during their lifetime. Although cigarette smoking was common in these subjects, alcohol use was not frequent with about 11% of the women reporting drinking any kind of alcohol. Using the BMI criteria, 2.2% of subjects were underweight; 25.6% of women were in the healthy weight range; 35.6% were over-weight; and 36.7% were obese.

Forty two percent (n = 38) of women were post-menopausal, with the duration of post-menopause being between 1 and 32 years. Post-menopausal women had significantly higher age and parity and lower height, lumbar spine and femoral neck BMD, but no significant differences were found between the pre-and post-menopausal women in weight, BMI, dairy calcium intake, exercise, smoking status, duration of smoking, and alcohol use (Table 1).

Table 1: Clinico-demographic characteristic of study subjects

|                     | Pre-menopause | Post-menopause | p value |
|---------------------|---------------|----------------|---------|
| N                   | 52            | 38             |         |
| Age (years)*        | 43.6 ± 4.7    | 55.18 ± 7.4    | <0.001* |
| Height (cm)*        | 157.7 ± 5.5   | 155 ± 5.7      | 0.027*  |
| Weight (kg)*        | 70.8 ± 16.4   | 68.9 ± 10.3    | 0.530*  |
| BMI (kg/m²)*        | 28.5 ± 6.9    | 28.7 ± 4.3     | 0.869*  |
| LSBMD (g/cm²)*      | 1.19 ± 0.15   | 1.04 ± 0.16    | <0.001* |
| FNBMD (g/cm²)*      | 0.97 ± 0.12   | 0.87 ± 0.11    | <0.001* |
| Dairy calcium intake (mg/day)* | 410 ± 262 | 498 ± 306 | 0.147*  |
| Age at menopause*   | -             | 47.9 ± 4.02    |         |
| Parity†             | 2 (2, 3)      | 3 (2, 4)       | 0.004†  |
| Regular exercise§   | 12 (23.1)     | 11 (28.9)      | 0.528§  |
| Smoking status       |               |                |         |
| Current smokers     | 15.4 (8)      | 21.1 (8)       | 0.487§  |
| Ex-smokers          | 21.2 (11)     | 23.7 (9)       | 0.775§  |
| Duration of smoking (years)§ | ≤ 5  | 4 (33.3) | 1 (9.1) | 0.155§  |
|                      | > 5           | 8 (66.7)       | 10 (90.9) |
| Alcohol use§        | 7 (13.5)      | 3 (7.9)        | 0.407§  |

*Mean ± SD; †median (interquartile range); § n (%).
unpaired t-test, *Mann-Whitney U test; †Chi-square test.
BMI, body mass index; LSBMD, lumbar spine bone mineral density; FNBMD, femoral neck bone mineral density.
Determinants of BMD

In simple linear regression analysis, age, height, weight, BMI, menopausal status, smoking habits, duration of smoking, and cigarette dose were each significantly associated with LS and FN BMD (Table 2). However, in the multiple linear regression, advancing age, lower BMI and smoking were independent predictors of LS and FN BMD (Table 3). After adjusting for age and BMI, smokers had 0.087 g/cm² (8%) and 0.075 g/cm² (8%) lower in LS and FN BMD, respectively, than non-smokers. The 3 factors collectively accounted for 30% and 38% of the variation in LS and FN BMD, respectively.

As expected, advancing age was negatively associated with BMD in the both sites (LS: \( r = 0.45, p = 0.0001 \); FN: \( r = 0.50, p = 0.0001 \)). Nevertheless, there was a significant positive correlation between BMI and LS and FN BMD (LS: \( r = 0.22, p = 0.033 \); FN: \( r = 0.26, p = 0.012 \)). Current smokers had significantly lower lumbar spine and femoral neck BMD than non-smokers. However, there was no significant difference between ex-smokers and non-smokers in both BMD sites (Fig. 1). Among smokers, there was no significant linear correlation between cigarette dose and BMD (\( p = 0.14 \) for LSBMD and \( p = 0.64 \) for FNBMD) and duration of smoking and BMD (\( p = 0.76 \) for LSBMD and \( p = 0.86 \) for FNBMD).

Further analysis of interaction between BMI and smoking revealed that the effect of smoking was only observed in the obese group (\( p = 0.029 \) for LS and \( p = 0.007 \) for FN), but not in the overweight and normal groups (Fig. 2). This interaction effect was not affected by the dose of cigarette or duration of smoking. Moreover, there was a non-statistically significant interaction between age and smoking, as both smokers and non-smokers appeared to have a similar age-BMD association (Fig. 3).

Prevalence of low bone density

Twenty-five women (27.8%) were osteopenic (T-score -1 to -2.49) at the lumbar spine and 32 (35.6%) at the femoral neck. Using the WHO T-score-based definition of osteoporosis, the proportion of women with osteoporosis was 12.2% (\( n = 11 \)) at the lumbar spine and 2.2% (\( n = 2 \)) at the femoral neck. When the two measures were considered simultaneously, the prevalence of osteoporosis was 13.3%. In post-menopausal women, the prevalence of osteoporosis (T-score ≤ -2.5) was 23.7% (\( n = 9 \)) at the
Mean and standard error of lumbar spine (upper panel) and femoral neck (lower panel) bone mineral density (g/cm²) by smoking status.

**Figure 1**
Mean and standard error of lumbar spine (upper panel) and femoral neck (lower panel) bone mineral density (g/cm²) by smoking status.
Mean and standard error of lumbar spine (upper panel) and femoral neck (lower panel) bone mineral density (g/cm²) by body mass index and smoking status.

**Figure 2**
Mean and standard error of lumbar spine (upper panel) and femoral neck (lower panel) bone mineral density (g/cm²) by body mass index and smoking status.
Interaction between age and smoking status on lumbar spine (upper panel) and femoral neck (lower panel) bone mineral density (g/cm²).

**Figure 3**
Interaction between age and smoking status on lumbar spine (upper panel) and femoral neck (lower panel) bone mineral density (g/cm²).
Alcohol use was not significantly associated with bone density. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. The results also revealed a non-significant association. 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Competing interests
The author(s) declare that they have no competing interests.

Authors’ contributions
Conception and study design: AB, JE, TN
Data collection: AB, NP
Drafting manuscript: AB
Data analysis: AB, NN, TN
Review of manuscript for important intellectual content: AB, NN, TN
All authors read and approved the final manuscript.

Acknowledgements
The Iranian Ministry of Health and Medical Education is thanked for the award of a scholarship to AB. The authors acknowledge the assistance of Ms Fiona McGrath in the measurement of bone densitometry. We wish to express our thanks to A/Prof Jan Ritchie for her comments. We would like to thank Mr. Hamid Atighpour for his assistance with the data collection. We also thank the Iranian women for their participation in this study.

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Pre-publication history
The pre-publication history for this paper can be accessed here:

http://www.biomedcentral.com/1471-2474/6/34/prepub