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Relationship between Lumbar Bone Mineral Density (BMD) and Body Mass Index (BMI) in Pre-Menopausal Population. A Large Cohort Study

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Abstract

Background: Osteoporosis is a multifactorial disease. The body mass index (BMI) can affect bone density (BMD) with higher BMI scores that seems to be protective for osteoporosis in postmenopausal women. Primary aim of this study was to relate BMI and lumbar BMD in pre-menopausal females.

Methods: We obtained from our local registry demographic and anthropometric data of females aged 20 years or older that performed their first DEXA in our Hospital between 2006 and 2014. Criteria for patient selection were: absence of known risk factors of Osteoporosis (e.g., smoke, alcohol, metabolic disease that affects bone, fractures), a concomitant or previous treatment of osteoporosis or corticosteroids or other drugs affecting bone (e.g., thyroid hormones, oral anticoagulant, immunosuppressant drugs). Data collection included also Calcium, PTH and 25-OH vitamin D levels and a structured data sheet covering the medical and drug use history, and lifestyle habits, including smoking, consumption of alcohol and coffee, physical activity and calcium intake.

Patients with low or high BMI (over 95 percentile) were eligible. Osteopenia (low bone density) and osteoporosis (very low bone density) were defined by T- score <-1 and <-2.5, respectively.

Results: 1197 DEXA scan analysed. Mean age was 34.2 ± 1.8 years (range 20.8 to 45.7). Mean BMI was 27.2 ± 3.9 kg/m^2 (range 15 to 36). Mean menarche age was 16.3 ± 5 years (range 11-17). The prevalence of low bone density (T score between -1 and -2.6) and very low bone density (T score <2.6) were 24.1% and 13.8%, respectively. Mean calcium and 25-OH vitamin D levels were 9.3 mg/dl (range 8.7-10.4 mg/dl) and 27 ng/ml (range 6-75 ng/ml) respectively. Using a statistical model adjusted all variables collected, we found a reverse correlation between BMI and calcium dietary intake. BMI values were related to BMD in a non-linear way with the lowest BMD observed with the extreme BMIs < 15 kg/m^2 and > 30 kg/m^2.

Conclusion: Our study showed a peculiar relationship between BMI and BMD values in pre-menopausal women that look like a parabolic curve, with lower BMD at extreme BMI levels.

Keywords: Osteopenia; Osteoporosis; Bone mass index (BMI); Bone mineral density (BMD)

Introduction

Osteoporosis is a metabolic skeletal disease characterized by reduced BMD, which may lead to an increased risk of bone fractures [1-4]. It's generally considered a disorder of postmenopausal women, but low BMD and accelerated bone loss can also be observed in pre-menopausal patients, overall in subjects with diseases like primary hyperparathyroidism, Cushing's syndrome, and thyrotoxicosis, that promote accelerated bone loss. Body mass index (BMI) is one of the modifiable factors affecting BMD. In the past, low BMI has been advised a risk factor for fracture, and on the other hand overweight has been considered a protective factor [5-8]. Recent literatures have otherwise reported that obesity was associated with an increased risk of ankle and upper leg fractures. Aim of our study was to establish the relationship between BMI and BMD in pre-menopausal women analysing data of a large cohort of subjects [9-16].

Materials and Methods

Methods

Demographic (age, age at menarche, life style, physical activity, calcium dietary intake), anthropometric (BMI) and serological (calcium levels, 25-OH vitamin D3, PTH) data of females aged 20 years or older that performed their first DEXA in our Hospital between 2006 and 2014 were retrospectively extracted from our local registry using a random sampling technique. BMD was determined using dual-energy X-ray absorptiometry (DXA) on a Hologic bone densitometer (QDR 9000 Hologic, Waltham, Mass). Criteria for data-patient choice were absence of known risk factors of osteoporosis (e.g., smoke, alcohol, metabolic disease that affects bone, fractures), a concomitant or previous treatment for osteoporosis, contraceptive pills, corticosteroids or other drugs affecting bone. Patients with low or high BMI (over 95 percentile) were eligible. Low bone density and very low bone density were defined using the WHO definitions for osteopenia and osteoporosis: T- score <-1 and <-2.5, respectively. In this study, we used the WHO BMI classification: underweight <18.5 kg/m^2; normal weight 18.5-24.9 kg/m^2; over weight 25-29.9 kg/m^2;

obese>30 kg/m^2. BMI was calculated as weight (kg)/height (m^2); Data about the estimated weekly calcium intake and physical activity were collected too. On the basis of tables of nutrient values issued by the Italian National Institute of Nutrition, calcium intakes from some selected calcium-rich foods (milk and dairy products) were assessed. The foods checked represent the major sources of daily calcium intake in the Italian diet, including milk, aged cheese, soft cheese, cottage cheese, and yogurt. Portion sizes were quantified by using means of household measures (slices, cups, and glasses). Data were categorized according to quartiles of weekly servings (<7, 7-11, 12-15, and >15). Spare-time physical activity was assessed by the reported number of 20 min sessions of leisure-time physical activity per week, and physically active behaviour was defined as participation in >2 sessions/week. Occupational physical activity was assessed for employed women and was classified as light (office clerks and other sedentary jobs) or heavy (manual work).

Statistical analysis

After testing for normality of the distribution (Shapiro-Wilks test), the baseline variables were compared with ANOVA and by chi-square test for linear trend when dealing with continuous variables or categorical variables, respectively.

All the variables that were statistically significant in a univariate analysis were considered. In a multivariable analysis, a generalized linear model was used to assess the predictors of BMD. To identify the factors associated with the probability of having low bone density, further stepwise multiple logistic regression analyses were performed. All of the statistical tests were 2-sided at the 5% level and were performed by using SPSS software.

Results

1197 DEXA scan analysed. Mean age was 34.2 ± 1.8 years (range 20.8 to 45.7). Mean BMI was 27.2 ± 3.9 (range 15 to 36). Mean menarche age was 16.3 ± 5 (range 11-17). The prevalence of low and very low bone density (T score between -1 and -2.5 and T score <2.6) was 24.1% and 13.8 respectively. Mean calcium and 25-OH vitamin D levels were 9.3 mg/dl (range 8.7-10.4 mg/dl) and 27 mg/ml (range 6-75 mg/ml).

Significant differences were observed when mean BMIs between the dairy calcium intake quartiles were compared; significant decreases from the lowest to the highest quartile and the prevalence of overweight subjects in the lowest quartile (33.6%) was nearly 3 times that in the highest quartile (14.1%) (Figure 1).

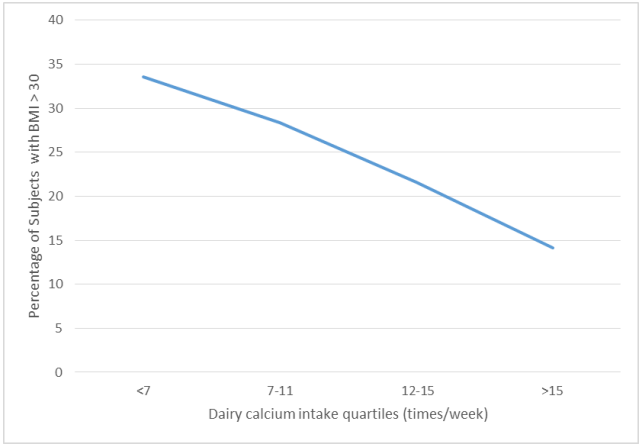

Figure 1: Prevalence of obese subjects (BMI >30 kg/m^2) in the dietary quartiles.

The univariate ANOVA model showed a significant relationship between BMD values and physical activity, age, smoking status, calcium intake and BMI. The general linear model (GLM) showed a non-linear relationship between BMD and BMI, also when the statistical model was adjusted for the other variables collected (age, age at menarche, PTH, calcium and [25] OH vitamin D levels, dietary calcium intake, physical activity). The BMD values observed were: for BMI <15 kg/m^2:0.78, for BMI between 15.1 and 18 kg/m^2:0.88, for BMI between 18.1 and 25 kg/m^2:0.93, for BMI between 25.1 and 30 kg/m^2: 1.11, for BMI above 30 kg/m^2:0.9.

So, the highest BMD values were observed in overweight subjects with BMI between 25.1 and 30 kg/m^2 and the lowest in subjects with a BMI <15 kg/m^2 or >30 kg/m^2 resulting in an inverse U shaped curve of relationship (Figure 2).

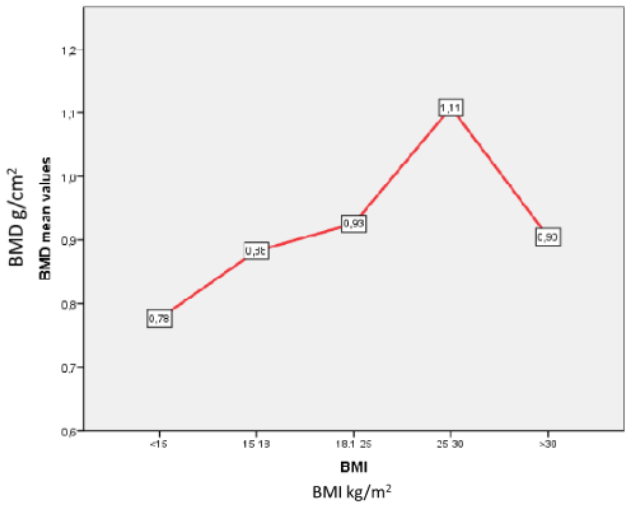

Figure 2: Relationship between BMI (kg/m^2) and BMD (g/cm^2).

Discussion

Osteoporosis is a skeletal disorder characterized by decreased BMD and by deterioration of bone micro-architecture with increased risk to fracture and have to be considered a multifactorial disease both in post than in pre-menopausal women. Risk factors of premenopausal osteoporosis include the following: genetic influences, ethnicity, hormonal influences, nutritional factors, physical activity, disease factors, medications, and smoking [5]. Racial and ethnic differences in BMD values have been reported, and population norms have been established for use as DXA reference standards [17-21]. Overweight individuals have a higher bone mineral density (BMD) than individuals of lesser body weight and they seem to be more protected against bone fractures than underweight subjects are [22-25]. Weight loss significantly decreases absolute BMD because of it is responsible of less loading on the bones, a decrease in parathyroid hormone (PTH) causing renal calcium loss, and a decrease in extra ovarian estrogenic synthesis [26-29]. James Wee et al. demonstrated that in postmenopausal women, lower BMI was associated to worse BMD [30]. Barrera et al. confirmed that the risk for osteoporosis among men and women with a BMI above 30 kg/m^2 was approximately 33% compared with subjects with a normal BMI [31]. Kirchengast S et al. showed that a lower weight status and a low amount of lean body mass are associated to an increased bone loss and the development of osteoporosis in both sexes [32]. Greater muscle mass seems to be associated with higher bone mass, likely due to the increased mechanical stress of muscle on bone [33]. Today it isn't known how much body weight is needed to confer a reduced risk of osteoporosis. Generally, a BMI of 30 is associated with a 4-8% greater lumbar spine BMD, 8-9% greater hip region BMD, and 25% greater radius BMD compared with a BMI of about 20 [34-35]. However, today no value is agreed on for weight to height versus osteoporosis and related fracture risk, but a BMI of 26-28 has been suggested to confer some protection, whereas a BMI of 22-24 has been thought to increase risk [36-38]. When we refer to lean or fat mass, cross sectional studies have reported BMD to be proportional to lean mass rather than fat mass [39-42]. Although cross-sectional studies have reported inverse relationships among fat mass and BMD, to date no longitudinal study has been performed to demonstrate this relationship among the same individuals [43]. Janicka et al. showed that in young men and women (13-21 years) the femur and spine BMD are inversely correlated with fat mass once lean mass was adjusted for [44]. In our study, similarly to previous studies, absolute spine BMD decreased with weight loss [45-47]. This was expected since there was a decrease of mechanical loading on the bones. Focusing on overweight patients, we found that BMD decreased, also when the BMI was >30 kg/m^2. These data confirm the literature about the negative influence of fat mass (that is present especially in overweight patients) on BMD. As weight increases beyond a BMI of 30, a woman may experience relative immobility and increased tendency to fall, so an increased body weight confers no advantage to skeletal health when this increase becomes excessive. Our study has shown a different role of BMI on BMD values: there is a trend that looks like a parabolic curve, with lower BMD at BMI levels of underweight or overweight. Our study has some weaknesses. The main limitation is related to its retrospective and observational nature. Measurement of dietary calcium intake at a single time point may not reflect long-term exposure. Furthermore, no data are available about the lean mass. In conclusion, our data suggest that, in a healthy sample of premenopausal women, a low dietary calcium intake is associated with a high BMI and a low BMD. On the other hand, a high BMI has a negative effect on BMD values.

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