Original Article

Bone mineral density of vegetarian and non-vegetarian adults in Taiwan

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Diet is thought to be one of the leading causes of bone mineral loss in aging people. In this study, we explored the potential impact of a vegetarian diet on bone mineral density (BMD) in adult Taiwanese men and women. This was a cross-sectional study of the relationship between diet (vegetarian versus non-vegetarian) and BMD and the incidence of osteoporosis. Bone mineral density was determined in a cohort of 1865 adult male and female patients who underwent routine examination in a regional teaching hospital in Taiwan between February 2003 and February 2004. Subjects with definite vertebral problems, known osteopathy, or poor posture were excluded. Dual-energy X-ray absorptiometry (DEXA) was used to determine BMD, on the right hip in men and on lumbar vertebrae L2 to L4 in women. The subjects were grouped according to sex and diet, and were then stratified by age within each of the four groups. The outcome measures were the BMD value and the incidence of osteopenia or osteoporosis according to defined criteria. Bone mineral density gradually declined with increasing age in Taiwanese men, while Taiwanese women showed a precipitous decrease in BMD after the 5th decade. However, no statistical differences in BMD were observed between vegetarians and non-vegetarians of either sex. The proportion of subjects with osteopenia or osteoporosis also appeared comparable between vegetarians and non-vegetarians of either sex. BMD shows an age-related decline in Taiwanese men and women, and eating a vegetarian diet does not appear to affect this decline.

Key Words: diet, bone mineral density, osteoporosis, vegetarian, non-vegetarian

INTRODUCTION

Advances in medical technology and improvements in economic status and living standards have greatly prolonged the life span of human beings. Consequently, the proportion of elderly people within the population is increasing. In response to the aging of society, countries around the world are aggressively implementing programs for disease prevention. In addition to other conditions such as cardiovascular disease, malignancy, and metabolic problems; osteoporosis and its prevention has become progressively more important.[1] Therefore, a study of bone mineral density (BMD) has practical and clinical value.

Osteoporosis, or bone mineral loss, has several etiologies that may act together. The two most common causes of primary osteoporosis are hormonal changes that lead to a loss of bone mass in postmenopausal women[2] and natural degeneration in aging people of both sexes. Other factors, such as race, gender, physical constitution, lifestyle, exercise, sunlight, diet, and drugs[3] also influence the rate of bone formation or re-absorption and lead to changes in bone mineral content.

The health benefits of eating a natural and balanced diet, including meat and vegetables, have been long recognized in traditional Chinese society. Most people still believe that foods from animal sources are more nutritious than those from plants. For many centuries, animal-based foods were relatively scarce, expensive and not available for every meal; therefore they were highly valued.

However, vegetarianism in Asia originates from the Buddha's teaching of "no killing", and it has been practiced by a small group of Buddhists for centuries. Most vegetarians eat dairy products and eggs in addition to plant-derived food (ovo-lactovegetarians).[4] In Taiwan, the prevalence of vegetarianism is estimated as 2.3% in men

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and 4.4% in women who are older than 45 years of age.[5]

The modern Buddhist vegetarian diet is similar to the usual Taiwanese diet in terms of meal pattern, cooking methods, choice of staple (primarily rice), and consumption of fruits and vegetables. Taiwanese vegetarian diets include large amount of soybean products as the major substitute for animal products.[6] As reported in a nutritional survey, Taiwanese vegetarians consume fewer calories, more carbohydrates (63% of calories for men, 58% for women) and less protein (12% of calories) and fat (25% for men, 30% for women) compared with non-vegetarians. The ratios of polyunsaturated/saturated (P/S) and polyunsaturated/monounsaturated (P/M) fatty acids in the Taiwanese vegetarian diet are high (P/S=3.4, P/M =2.5), with the mean P/S ratio in vegetarian diet being approximately two times that in the diet of non-vegetarians.[6]

The purpose of our study was to explore the effects of two different diets, vegetarian and non-vegetarian, on BMD values in an adult Taiwanese population. We postulate that the average BMD would be lower and the incidence of osteoporosis higher in Taiwanese vegetarians as compared with non-vegetarians due to the lower protein intake. Because Taiwan is a small island with a dense population, investigating this relatively uniform group, with regard to factors such as genetics, environmental factors, and racial or constitutional parameters, allowed us to determine whether any differences in BMD might be related to differences in diets.

SUBJECTS AND METHODS

Study subjects

BMD data were obtained from a case review of adult men and women (older than 21 years) who underwent routine examination in a regional teaching hospital in the west-central region of Taiwan between February 2003 and February 2004. Cases with any of the following conditions were excluded: 1) notable osteopathy such as traumatic fracture or compressive fracture; 2) osteomyelitis or other inflammatory osteopathy; 3) scoliosis or poor posture; 4) degenerative changes of the spinal cord, or bone spur formation; and 5) surgically or medically-induced menopause.

The subjects were then classified into four groups on the basis of their sex and their self-reported dietary preference as vegetarian (for at least 5 years) or non-vegetarian.

BMD measurements

BMD values were obtained using dual-energy X-ray absorptiometry (DEXA) with an Excell^{TM} plus machine (Norland Corp., Fort Atkinson, WI). The average density of the right hip (femoral neck area) in males or the average density of the second to fourth lumbar vertebrae in females was measured in units of gm/cm^2. A database of BMD values in Chinese people was used as the reference population.[7] A Certified Clinical Densitometrist (CCD) who was certified by the International Society for Clinical Densitometry (ISCD) reviewed the images and rechecked the reports.

Statistical analysis

For the analysis of age-related BMD changes, the subjects were classified into seven age groups (from 20 to 89 years, divided in decades). Since age is a confounder, the Mann-Whitney test was used to compare the differences for each age group. Means and 95 percent confidence intervals for BMD were calculated. The Chi-square test was used to study the associations between diet and other factors affecting bone health (i.e. milk drinking, calcium pills, and hormone replacement therapy). Statistical analyses were performed using SAS statistical software, version 8.2 (SAS Institute, Cary, North Carolina). All reported *p* values were two-sided.

Ethics

This study was conducted in accordance with the internationally agreed ethical principles for the conduct of medical research.

RESULTS

A total of 1865 men and women were included. Of these, 383 (20.5%) were vegetarian men, 464 (24.9%) were non-vegetarian men, 489 (26.2%) were vegetarian women and 529 (28.4%) were non-vegetarian women.

The average BMD values for each group are presented in Table 1. Comparisons between vegetarians and non-vegetarians did not show any statistically significant differences in BMD in either men or women.

The numbers of vegetarian and non-vegetarian subjects

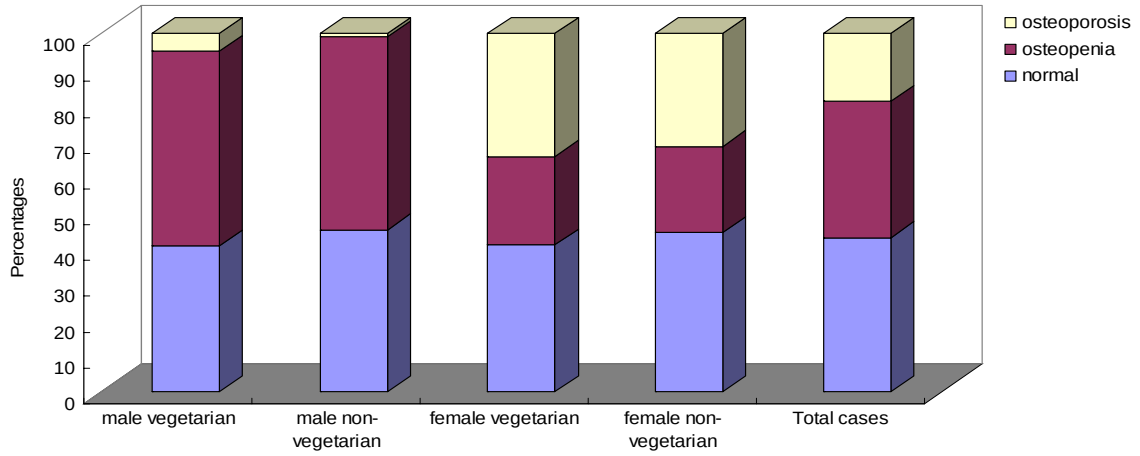

Figure 1

Table 1. Bone Mineral Density (gm/cm^2) in Adult Taiwanese, by Sex and Diet

	Sex	
Diet	Male	Female
Vegetarian	0.813 ± 0.127† (N=383)	0.953 ± 0.179 (N=489)
Non-vegetarian	0.829 ± 0.142 (N=464)	0.968 ± 0.183 (N=529)
p value ‡	0.22	0.22

† Results are presented as mean ± standard deviation
‡ Comparison between diets within sex group using Mann-Whitney U-test.

who reported milk drinking or other measures thought to be related to improved bone health are shown in Table 2 for men and in Table 3 for women. No significant association (p>0.05) were observed between the use of milk, calcium supplements or hormone replacement and loss of bone density in these groups, with one exception. Within the group of non-vegetarian women, consumption of calcium pills was significantly associated with lower bone density (p=0.016).

Figure 1 shows the distribution of the extent of bone mineral loss according to WHO criteria within each of the 4 groups. Vegetarian men were similar to non-vegetarian men with regard to the incidence of osteopenia or osteoporosis, as were vegetarian women compared with non-vegetarian women.

The average BMD was plotted by age range for men and women. Figure 2 shows that in men, BMD gradually declined with age and that the age profiles were not significantly different for vegetarians and non-vegetarians. Women showed a precipitous drop in BMD from 5th decade onward (Figure 3), probably coinciding with menopause. The profiles in female vegetarians and non-vegetarians were almost super-imposable and were not statistically different.

DISCUSSION

Sex, Ethnicity and Age

Osteoporosis, a metabolic bone disease characterized by low bone mass and increased susceptibility to fracture, is a disease not only found in women, but also in men. There are definite differences in the prevalence, anatomy, pathogenesis, diagnosis and treatment of osteoporosis in men as compared to women.[10-12] The age-related decline in BMD in men seems to result from an age-related decline in the levels of bio-available estrogen.[13]

BMD values have been reported to be lower in Taiwanese compared to Caucasians,[14,15] and there appears to be differences with regard to the degree of age-related decline in BMD among the Japanese, Koreans and Taiwanese. However, the age-related decline of BMD in men and women observed in our study is similar to other published reports on Caucasians[16] and the Taiwanese population.[14,15,17]

Diet

There have been conflicting reports regarding the effect of vegetarian diets on bone mineral density. Lloyd reported no significant difference in spinal bone density of premenopausal vegetarian and non-vegetarian women.[18]

Table 2. Relationship between extent of bone mineral loss and use of milk or calcium pills in vegetarian and non-vegetarian men

	Vegetarian Men (N=383)				Non-Vegetarian Men (N=464)			
Classification†	Normal N (%)	Osteopenia N (%)	Osteoporosis N (%)	*p* value‡	Normal N (%)	Osteopenia N (%)	Osteoporosis N (%)	*p* value
Milk drinking								
Yes	107 (28%)	142 (37%)	11 (3%)	0.4478	169 (36%)	162 (35%)	4 (1%)	0.1223
No	57 (15%)	59 (15%)	7 (2%)		55 (12%)	74 (16%)	0 (--)	
Calcium pills								
Yes	22 (6%)	32 (8%)	4 (1%)	0.5549	27 (6%)	39 (8%)	1 (<1%)	0.3288
No	142 (37%)	169 (44%)	14 (4%)		197 (42%)	197 (42%)	3 (1%)	

†Extent of bone mineral loss is classified using T-scores as normal (T>-1.0), osteopenia (-1.0≥T≥-2.5), or osteoporosis (T<-2.5).
‡From Chi-square test for r-by-c table.

Table 3. Relationship between extent of bone mineral loss and use of milk, calcium pills or hormone replacement therapy in vegetarian and non-vegetarian women

	Vegetarian Women (N=489)				Non-Vegetarian Women (N=529)			
Classification†	Normal N (%)	Osteopenia N (%)	Osteoporosis N (%)	*p* value‡	Normal N (%)	Osteopenia N (%)	Osteoporosis N (%)	*p* value
Milk drinking								
Yes	155 (32%)	73 (15%)	102 (21%)	0.6271	166 (31%)	81 (15%)	103 (19%)	0.4996
No	69 (14%)	41 (8%)	48 (10%)		92 (17%)	42 (8%)	44 (8%)	
Calcium pills								
Yes	61 (12%)	28 (6%)	51 (10%)	0.1969	53 (10%)	39 (7%)	46 (9%)	0.0167
No	163 (33%)	86 (18%)	99 (20%)		205 (39%)	84 (16%)	101 (19%)	
HRT								
Yes	21 (4%)	17 (3%)	21 (4%)	0.2319	24 (5%)	20 (4%)	14 (3%)	0.1019
No	203 (42%)	97 (20%)	129 (26%)		234 (44%)	103 (19%)	133 (25%)	

†Extent of bone mineral loss is classified using T-scores as normal (T>-1.0), osteopenia (-1.0≥T≥-2.5), or osteoporosis (T<-2.5).
‡ From Chi-square test for r-by-c table.

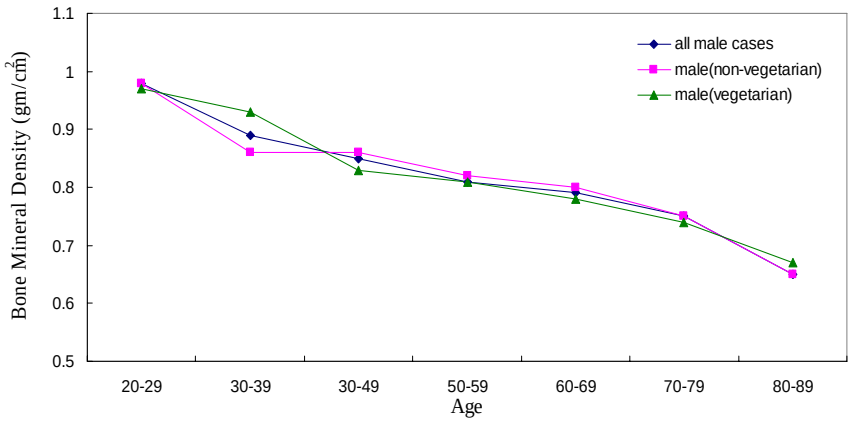

Figure 2

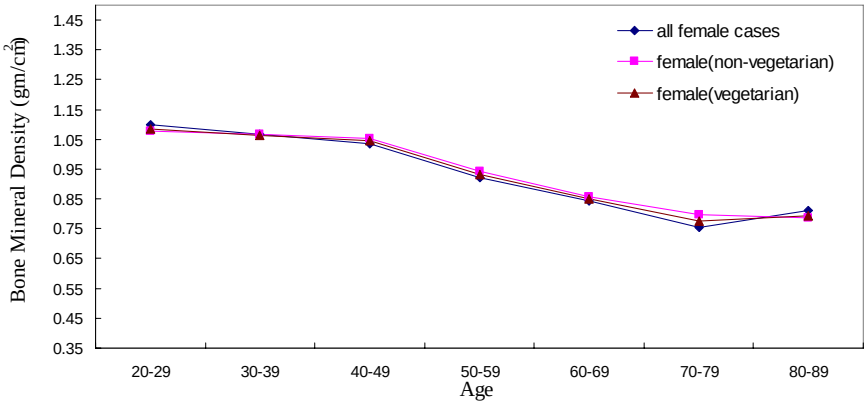

Figure 3

Tesar reported that neither cortical nor trabecular bone density in postmenopausal women differed in ovolactovegetarians compared with non-vegetarians.[19] Marsh, in a study of 1600 women in southwestern Michigan, revealed that those who had followed the ovolactovegetarian diet for at least 20 years had a reduction of only 18% in bone mineralization by age 80 as compared with a 35% reduction in women on an non-vegetarian diet.[20] However, Chiu reported that long-term vegetarianism was related to a higher rate of osteopenia in postmenopausal Taiwanese women.[21] Lau reported that in elderly Chinese women, the bone mineral density at the hip was lower in vegetarians than in non-vegetarians.[22]

Our study demonstrated no significant differences in BMD between vegetarians and non-vegetarians. However, there are two major differences between our study and theirs: first, both studies included mostly strict vegetarians (vegans or lactovegetarians) and our study included mainly ove-lactovegetarians. Second, they studied long-term vegetarians (at least 15-30 years) and we studied only medium term vegetarians (at least 5 years). It remained to be investigated whether the more strict vegetarian diets and longer duration of being on a vegetarian diet could explain the different results.

The Dietary Approaches to Stop Hypertension (DASH) trial demonstrated that the DASH diet (emphasizing fruits, vegetables, and low fat dairy products, including whole grains, poultry, fish and nuts) significantly reduced markers of bone turnover, which might improve bone mineral status if sustained.[23] The potentially beneficial effects on health of dietary phytoestrogens (i.e., isoflavonoids, stilbenes, coumestans and lignans) have also been reported.[24]

The dietary intake of Taiwanese vegetarians and non-vegetarians are similar to the diets of the Chinese but quite different from those of Caucasians.[22] Although Chinese vegetarians consumed significantly fewer total calories, less protein, less fat, and more calcium, sodium and potassium than Chinese non-vegetarian, none of these dietary differences was found to be significantly associated with BMD.[22]

Taiwanese vegetarian diets include large amount of soybean products[6] instead of milk, cheese and eggs; which are commonly used in the western ovo-lactovegetarian diets as a substitute for meat products. Because soy isoflavones and soy phytoestrogen have been shown to have favorable effects on BMD in postmenopausal women,[25,26] the use of soy products is another possible explanation for the observation that BMD did not differ between vegetarians and non-vegetarians in our study.

The remodeling of bone is a continuous and complex process. Vitamin D, thyroid hormone, parathyroid hormone, sex hormones, dietary intake of protein, calcium, caffeine consumption, alcohol intake, cigarette smoking and physical activity are factors that may be important in modulating the rate of bone remodeling.[27]

We expected that the average BMD would be lower and that the incidence of osteoporosis higher in vegetarians compared with non-vegetarians. The fact that we did not find a significant impact of the vegetarian diet on

age-related decline of BMD in our study population of adult Taiwanese, may indicate that other unknown factors influence the development of osteoporosis. Further studies are necessary to elucidate the impact of individual dietary components on BMD.

AUTHOR DISCLOSURES

Yuh-Feng Wang, Jainn-Shiun Chiu, Mei-Hua Chuang, Jing-Er Chiu and Chin-Lon Lin, no conflicts of interest.

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台灣地區成年人骨質密度與素食與否之關聯性研究

長期以來，飲食型態一直被認為是與老年人骨質流失的情形有相當的關連性。這個研究中，我們旨在探討素食對於台灣地區成年人的骨質密度的影響，我們以此橫斷性研究來瞭解飲食習性(素食與非素食)與骨質密度間的關係，並同時探討與骨質疏鬆症間的相關性。本研究收集台灣某區域教學醫院自 2003 年二月起至 2004 年二月止接受一般常規骨質密度檢查的成年男性與女性，共 1865 位受試樣本，其中已排除包括脊椎病變、骨病變、或姿態不良者。研究中所採用的骨質密度分析儀為雙能量 X 光吸收儀，男性受試者偵測右側髖關節、女性受試者收集第二至第四腰椎之骨質密度；受試樣本依其性別、飲食習性區分為四個主要分組，再依年齡層分別進行統計，計算其骨質密度值、骨質流失、以及骨質疏鬆症之發生機率等。結果發現，在台灣的成年男性，其骨質密度隨年齡增長呈現逐漸降低的趨勢，而女性則在 50~59 歲間出現大幅下降的情形。不過，分析結果顯示，不論性別，在素食者與非素食者間對於骨質密度值均沒有顯著的統計差異出現，而對於骨質流失或骨質疏鬆發生的機率也沒有顯著的不同。我們可以由這個研究中歸結：對於台灣地區的成年男女，骨質密度值會隨著年齡的成長呈現下滑的趨勢，然而素食與否，並不影響這個下滑現象。

關鍵字：飲食、骨質密度、骨質疏鬆、素食、非素食。