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Influence of Dietary Calcium to Phosphorus Ratio on Bone Density of Vegetarian and Non-Vegetarian Older Women

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To the Graduate Council:

I am submitting herewith a thesis written by Teresa Ann Davis entitled "Influence of Dietary Calcium to Phosphorus Ratio on Bone Density of Vegetarian and Non-Vegetarian Older Women." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Nutrition.

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INFLUENCE OF DIETARY CALCIUM TO PHOSPHORUS RATIO ON BONE DENSITY OF VEGETARIAN AND NON-VEGETARIAN OLDER WOMEN

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ABSTRACT

The purposes of this study were: to investigate the influence of dietary calcium, dietary phosphorus, and their ratios as observed in vegetarian and non-vegetarian subjects on their bone densities and to compare bone density, the dietary intakes of calcium and of phosphorus, and the ratio of calcium to phosphorus in vegetarian and non-vegetarian subjects.

After obtaining informed consent, data were collected on 43 vegetarian and 36 non-vegetarian women, 40 to 92 years old, who consumed self-selected diets. Dietary information was obtained from 7-day dietary records. Dietary supplements were also recorded. Measurements of height, weight, and bone density of the radius, ulna, and finger were made.

Nutrient intakes were calculated by computer using food composition values from U.S.D.A. Handbook Nos. 456 and 8 and information obtained from Worthington and Loma Linda Foods. Bone density values of the radius and ulna were obtained using a bone mineral analyzer developed by Norland-Cameron Company. A bone densitometer developed by the Department of Nutrition, The University of Tennessee, was used to determine bone density of the finger (left phalanx 5-2).

The mean age of 57.1 years in the vegetarian group (Veg) was not significantly different from that of 58.8 years in the non-vegetarian group (Non-veg) ($P>0.05$). There was no significant difference in weight (Veg = 137.7 lb; Non-veg = 141.6 lb) and in height (Veg = 63.5 in; Non-veg = 63.5 in) between groups ($P>0.05$). Mean values for

height and weight were not significantly different between the Veg and Non-veg groups when adjusted for the mean age of both groups (57.9 years). There was a significant decrease in height with age but not weight with age in both groups. The differences in decreased height with age between groups was not statistically significant.

The mean calcium and phosphorus intakes from food (Ca = 1017 mg; P = 1325 mg) and from food plus supplements (Ca = 1106 mg; P = 1346 mg) in the Veg group surpassed the RDA. In the Non-veg group, the phosphorus intakes from food (1114 mg) and from food plus supplements (1131 mg) were greater than the RDA. The RDA for calcium was also met from food plus supplements (838 mg) but not from food alone (784 mg) in the Non-veg group. There was a tendency for a decrease in calcium and phosphorus intakes with age in both groups. When the intakes were either adjusted or unadjusted for age, the Veg group generally consumed significantly greater amounts of calcium and phosphorus from food alone and from food plus supplements than did the Non-veg group. The calcium to phosphorus ratios from food (Veg = 0.74; Non-veg = 0.70) and from food plus supplements (Veg = 0.78; Non-veg = 0.72) unadjusted and adjusted for age were not significantly different between groups. No significant relationship between the calcium to phosphorus ratio and age in both groups was obtained.

There was no significant difference in the mean bone density measurements of the radius, ulna, and finger between the Veg and Non-veg groups unadjusted and adjusted for the mean age of both groups. A highly significant negative correlation between bone densities of the radius, ulna, and finger and age was obtained ($P<0.0005$). There

was no significant difference in the slopes of the regression lines of bone density of the radius on age between Veg and Non-veg groups.

In both the Veg and Non-veg groups, there was a significant positive correlation between bone density of the radius and height, and also between bone density of the radius and weight. However, when adjusted for age, these correlations were not statistically significant. There were also no significant differences in the slopes of the regression lines of bone density on height and bone density on weight between Veg and Non-veg groups unadjusted and adjusted for age.

In the Veg group, the phosphorus intake from food alone was positively related to bone density of the radius. Regression coefficients on other nutrient intakes were nonsignificant in the Veg group. In the Non-veg group, there was a significant positive relationship between bone density and the intakes of calcium and phosphorus from food and also the intakes of calcium, phosphorus, and their ratio from food plus supplements. When adjusted for the influence of age, however, there was no significant correlation between bone density of the radius and each of the nutrient intakes of both groups. The slopes of the regression lines for bone density on the calcium intake and the calcium to phosphorus ratio from food plus supplements were significantly different between groups. There were no significant differences between any of the regression lines of bone density on nutrient intake between Veg and Non-veg groups adjusted for age.

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CHAPTER I

INTRODUCTION

It has been said that osteoporosis, or the severe loss of bone mass, is inevitable with advancing age (1). However, it is possible that environmental manipulation, including that of diet, could retard the rate at which bone loss occurs.

Numerous factors have been associated with the development of osteoporosis, but 2 of the most promising fields of research may be that of vegetarianism and the ratio of calcium to phosphorus in the diet. To date, most of the studies reported in the literature concerning the influence of the ratio of calcium and phosphorus in the diet of humans on bone loss have been done on omnivores. Recently, however, there have been a few studies conducted with vegetarians as subjects.

The purposes of this study were: to investigate the influence of dietary calcium, dietary phosphorus, and their ratios as observed in vegetarian and non-vegetarian subjects on their bone densities and to compare bone density, the dietary intakes of calcium and of phosphorus, and the ratio of calcium to phosphorus in vegetarian and non-vegetarian subjects.

CHAPTER II

REVIEW OF LITERATURE

Bone Loss

Osteoporosis is characterized by the loss of both inorganic and organic constituents from the bone (1). Such a loss in adult humans and experimental animals is a well documented phenomenon of the aging process (1, 2, 3, 4, 5). Numerous studies have shown that in humans the absolute amount of bone increases during childhood and adolescence but decreases by the fifth decade (1, 2, 3, 6).

The progressive decrease in bone with aging occurs in both sexes but is more pronounced in women than in men (1, 2, 3, 7). Garn et al. (2) reported that bone loss in females approximates 8 percent per decade but in males only 3 percent per decade. The earlier onset of bone loss in women, as opposed to men, has been reported by Newton-John and Morgan (7). They stated that the decrease in bone density begins at approximately 35 to 45 years of age in women and about 45 to 65 years of age in men. The leveling off of the rate of bone loss in late life is not seen in females as it is in males (2).

The universality of bone loss with age is widely accepted, although differences in population groups have been reported. In studies of 3 Central American countries and of 2 distinct populations from the United States, no differences were detected in bone loss. Mazess and Mather (8) however, have reported that bone loss began at an early age in the North Alaskan Eskimos and occurred at an elevated rate.

Interrelationships of Calcium, Phosphorus, and Bone Density

The interrelationships of calcium intake, calcium metabolism, bone density, and bone metabolism are widely accepted. This is due to the tremendous amount of body calcium found in bone (9). Numerous investigations also support the interrelationships. Nordin (10) and Caniggia (11) have proposed that osteoporosis is due to long-continued negative calcium balance in those who require abnormally high calcium intakes, or those who are unable to adapt to decreased intakes. Nordin (12) also suggested that this causes a removal of mineral from the bone, reducing bone mass. It has been reported that osteoporotic patients have moved from negative to strongly sustained positive balance when given calcium supplements (10). Harrison et al. (13) observed that osteoporotic patients respond to a high calcium intake by increased retention of calcium. Mason et al. (6) reported that a low calcium intake is associated with low bone density.

Other investigations have indicated that there is no relationship between calcium deficiency and bone loss. Garn et al. (2) found that a low calcium intake is not associated with a low bone density and that a high calcium intake is not related to a high bone density. It has also been reported that rats can adapt to a decreased intake of calcium (14). Dudl et al. (15) found no change in the accelerated bone turnover of osteoporotic patients after 1 year of calcium infusions. It was also found that the loss of total body calcium in treated and untreated osteoporotics was similar.

It has been demonstrated that a high phosphorus diet leads to bone loss. Jowsey and Balasubramaniam (16) showed that phosphate

supplementation resulted in increased porosity of the bone in adult rabbits. Increased bone resorption was also found in chicks fed high phosphate diets (17). These findings were supported by studies in dogs (18), in ponies (19), in horses (20), and in cats (21).

Numerous studies have indicated that it is not only the absolute amounts of dietary calcium and phosphorus which have an influence on bone density but the dietary ratio of the 2 elements as well. Shah et al. (22) reported that a dietary calcium to phosphorus ratio of 2:1 resulted in a significantly greater femoral cortex thickness and mineral content than that of a 1:1 ratio in adult mice. Rats fed a diet of 0.6 percent calcium and 1.2 percent or 1.8 percent phosphorus showed a significantly lower calcium, phosphorus, and ash content of the femurs, lumbar vertebrae, and mandibles than those fed lower levels of phosphorus and the same amount of calcium (23). This corroborates other studies by Krishnarao and Draper (24) which showed that the calcium, phosphorus, and ash content, and breaking load of the femurs were lower in mice fed a calcium to phosphorus ratio of 1:1 than in those fed a 2:1 ratio in the diet. It has also been reported that rats which consumed a diet of 1.2 percent phosphorus and 1.2 percent calcium showed a lower content of calcium, phosphorus, and organic matter of the femur than those who were fed a diet of 0.6 percent phosphorus and 1.2 percent calcium (25).

It has been proposed by Krook et al. (21, 26, 27) that a deficiency of dietary calcium and/or an excess of dietary phosphorus increases bone resorption due to secondary hyperparathyroidism resulting from the decreased serum calcium concentration associated with excess

serum phosphate. Krook (27) further proposed that this dietary induced hyperparathyroidism results in osteoporosis which is initially manifested in excessive alveolar resorption of the jaw bone resulting in peridontal disease.

Numerous investigations support the proposal that a low calcium to phosphorus ratio in the diet leads to hypocalcemia which induces bone resorption by its effect on the parathyroid gland. A loss of bone in adult rats fed a 1:1 calcium to phosphorus ratio in the diet was not found in parathyroidectomized rats in contrast to intact rats (25). Kelly et al. (28) found a significant positive correlation between serum phosphate concentration and the level of bone resorption in osteoporotic human subjects. An increase in serum parathyroid hormone has been reportedly initiated by a small decrease in total and ionized calcium as a result of phosphate administration in man (29). LaFlamme and Jowsey (18) have reported increased serum parathyroid hormone levels and loss of bone from the terminal ulna and iliac crest bone in adult dogs fed phosphate supplemented diets. Schryver et al. (19) found decreased plasma calcium concentration and increased bone turnover in ponies fed 0.4 percent calcium and 1.2 percent phosphorus. Similar findings have been reported in horses (20). Ten-Lin et al. (30) recently reported that a high phosphorus intake resulted in a decreased concentration of plasma calcium in adult rats, but the level remained within normal range. However, an increase in serum phosphate concentration and/or a decrease in serum calcium concentration as a result of a low calcium to phosphorus ratio in the diet was not detected

in rats by either Draper et al. (23), Clark (31), or Newell and Beauchene (32) or in dogs by LaFlamme and Jowsey (18).

Vegetarian Diets

Although vegetarianism has been practiced since the beginning of man, there has been a recent upsurge in the number of individuals who subscribe to vegetarian diets (33, 34, 35). Numerous studies have shown no detrimental effects of vegetarian diets on the health and nutritional status of vegetarians. No significant difference has been found in the incidence of disease in vegans and omnivores (36, 37). In a review of the literature on vegan diets, Kurtha and Ellis (38) reported that except for a deficiency of Vitamin B12, vegan diets met the nutritional requirements and maintained the health of adult vegans as indicated by hematological, biochemical, and clinical studies. Findings by Hardinge and Stare (39) are similar.

A vegetarian diet, supplemented with dairy products, with or without eggs, is considered to be nutritionally adequate for all ages (40, 41). Hardinge and Crooks (40) found a greater consumption of milk in ovo-lacto-vegetarians than in non-vegetarians. Similar findings were also reported for both milk and cheese (39).

Studies differ as to the reported intake of calcium and phosphorus for vegetarians. Hardinge and Stare (39) reported daily intakes of 1600 mg and 1800 mg for calcium and phosphorus, respectively, in ovo-lacto-vegetarians and a 1000 mg calcium and 1600 mg phosphorus intake in non-vegetarians. These intakes exceeded the Recommended Dietary Allowances of 800 mg of calcium and of phosphorus in adults (42). In vegetarian adult men, Mirone (43) reported intakes

of 670 mg of calcium and 1460 mg of phosphorus during the winter months with comparable figures during the summer months being 1250 mg and 1640 mg, respectively. Brown and Bergen (34) reported a calcium intake of 455 mg and a phosphorus intake of 988 mg in vegetarian women 23 to 55 years of age.

Dietary intake data indicate a higher calcium to phosphorus ratio in vegetarians than in non-vegetarians. Calculations show a calcium to phosphorus ratio of 0.889 in ovo-lacto-vegetarians and a ratio of 0.625 in non-vegetarians. Ratios of 0.78 (43) and 1:1.2 (34) for vegetarians were obtained in similar studies. Henrikson (44) cited a calcium to phosphorus ratio of 1:2.8 for the average American diet.

The literature is not abundant in investigations on the effect of vegetarian diets on bone density of humans. Ellis et al. (45) reported that the bone density of vegetarians was significantly greater than that of matched omnivores, and further, that the decrease in bone density with age was not as pronounced in vegetarians as in non-vegetarians. However, the conclusions of the study have been questioned (46, 47).

CHAPTER III

EXPERIMENTAL PROCEDURE

Selection of Subjects

The subjects of this study were 43 vegetarian and 36 non-vegetarian women, 40 to 92 years old. Vegetarian subjects were recruited through Seventh-Day Adventist Churches in Knoxville and Collegedale, Tennessee. Non-vegetarians were primarily recruited through the Church of Jesus Christ of Latter Day Saints, Knoxville, Tennessee. All subjects were contacted by telephone or in person by project workers and asked to participate on a voluntary basis. Details of the research were explained to the subjects and consent forms (Appendix) were signed by all subjects before they were allowed to participate. Data were collected during the months of March through June of 1976.

Collection of Dietary Information

Dietary information was obtained from 7-day dietary records (Appendix) and dietary histories (Appendix). Oral and written instructions (Appendix) for measuring and recording food portions eaten were given. Measuring spoons, measuring cups, and plastic rulers were provided for each subject. Dietary histories and 7-day dietary records were returned personally or by mail.

Food portions recorded in the 7-day dietary records were summarized and coded. The quantity of food items eaten was converted to grams using food composition values from U.S.D.A. Handbook

Nos. 456 (48) and 8 (49). Nutrient composition of Worthington and Loma Linda foods was obtained from the manufacturers and code numbers were assigned. Code numbers and weights were transferred to data cards and the average daily intakes of selected nutrients were computer calculated using values from U.S.D.A. Handbook No. 8 (49). Nutrients from vitamin and mineral supplements were added manually.

Bone Density Measurements

Bone density scans were taken of a central pathway of the left phalanx 5-2 using the bone densitometer developed by the Department of Nutrition, University of Tennessee (50). Due to the elliptical shape of the bone and flesh, anteroposterior and lateral scans were made for calculation of the bone density. Bone density was expressed as X-ray equivalent grams of alloy per cubic centimeter of bone. The method has been fully described by Williams and Mason (51).

Bone density measurements of the radius and ulna were made using a bone mineral analyzer developed by Norland-Cameron Company.*

Anthropometric Measurements

At the time of bone density scanning, height and weight measurements were made on the women while wearing light clothing and with shoes removed.

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*Bone Mineral Analyzer Model #178.

Statistical Analysis

Means and standard error were calculated using the Statistical Analysis System developed by Barr and Goodnight (52). The unpaired t test was used to determine significant differences of the mean nutrient intakes and physical parameters between vegetarian and non-vegetarian groups (53). Analyses of covariance were made to determine the means adjusted for age and F values were calculated to determine significance of difference between the vegetarian and non-vegetarian groups.

Regression analysis was used to determine the regression coefficients of bone densities and nutrient intakes on age and also bone density of the radius on nutrient intakes. Partial regression analysis was used to calculate the regression coefficients of the bone density of the radius on nutrient intake adjusted for age. Analyses of variance were made. F values were used to determine whether bone densities and nutrient intakes were significantly related to age and whether bone density of the radius was related to nutrient intake (52). The test for homogeneity of regression was used to test the difference between the slopes of the regression lines for vegetarian and non-vegetarian subjects (54).

CHAPTER IV

RESULTS

The mean values for physical measurements of vegetarian and non-vegetarian subjects are presented in Table 1. The vegetarian group, hereafter designated Veg, had a mean age of 57.1 years and ranged in age from 40 to 92 years. The non-vegetarian group, hereafter designated Non-veg, ranged in age from 40 to 91 years and had a mean age of 58.8 years which did not differ significantly from that of the Veg group ($P>0.05$).

The mean weight of 137.7 lb in the Veg group did not differ significantly from that of 141.6 lb in the Non-veg group ($P>0.05$). There was also no difference in height (Veg = 63.5 in; Non-veg = 63.5 in) between groups. When adjusted for age (mean age of both groups = 57.9 years), the differences between weight (Veg = 137.3 lb; Non-veg 142.1 lb) and height (Veg = 63.4 lb; Non-veg = 63.6 lb) between the Veg and Non-veg groups were not statistically significant (Table 2). In the Non-veg group, there was a tendency for a decrease in height and weight per decade as indicated in Table 3. A tendency for a decrease in height and weight with age was noted in the Veg group after the fifth decade. When calculated by regression analysis, there was a significant decrease in height with age in both the Veg and Non-veg groups (Table 4). The decrease in weight with age in both groups was not statistically significant. The differences between the slopes of the regression lines for height and age and also weight and age between groups were nonsignificant.

TABLE 1

MEAN VALUES OF PHYSICAL MEASUREMENTS AND NUTRIENT INTAKES OF VEGETARIAN AND NON-VEGETARIAN SUBJECTS

	Vegetarians (N=43)	Non-vegetarians (N=36)	Significance of Difference[1]
Age (yr)	57.1±2.0[2]	58.8±2.1	N.S.
Weight (lb)	137.7±4.2	141.6±3.9	N.S.
Height (in)	63.5±0.4	63.5±0.4	N.S.
Bone Density			
Radius (g/cm^2)	0.68±0.01	0.67±0.02	N.S.
Ulna (g/cm^2)	0.69±0.02[3]	0.69±0.02	N.S.
Finger (g/cc)	1.12±0.04	1.18±0.04	N.S.
Nutrient Intakes			
Food			
Calcium (mg)	1017±79	784±39	Sign.
Phosphorus (mg)	1325±71	1114±43	Sign.
Ca: P Ratio	0.74±0.02	0.70±0.02	N.S.
Food Plus Supplements			
Calcium (mg)	1106±110	838±62	N.S.
Phosphorus (mg)	1346±79	1131±45	Sign.
Ca: P Ratio	0.78±0.02	0.72±0.03	N.S.

[1]Comparisons of vegetarians and non-vegetarians; Sign., $P<0.05$; N.S., $P>0.05$.

[2]Values expressed as mean ± SE.

[3]N = 23.

TABLE 2

MEAN BONE DENSITY VALUES AND NUTRIENT INTAKES OF VEGETARIAN AND NON-VEGETARIAN SUBJECTS ADJUSTED FOR AGE[1]

	Vegetarians (N=43)	Non-Vegetarians (N=36)	Significance of Difference[2]
Weight (lb)	137.3	142.1	N.S.
Height (in)	63.4	63.6	N.S.
Bone Density			
Radius (g/cm^2)	0.68	0.67	N.S.
Ulna (g/cm^2)	0.69[3]	0.69	N.S.
Finger (g/cc)	1.11	1.19	N.S.
Nutrient Intakes			
Food			
Calcium (mg)	1011	790	Sign.
Phosphorus (mg)	1320	1121	Sign.
Ca: P Ratio	0.74	0.70	N.S.
Food Plus Supplements			
Calcium (mg)	1099	846	N.S.
Phosphorus (mg)	1340	1138	Sign.
Ca: P Ratio	0.78	0.72	N.S.

[1] Mean age of both groups was 57.9 years.

[2] Comparisons of vegetarians and non-vegetarians; Sign., $P<0.05$; N.S. $P>0.05$.

[3] N = 23.

TABLE 3

PHYSICAL MEASUREMENTS AND NUTRIENT INTAKES OF VEGETARIAN AND NON-VEGETARIAN SUBJECTS BY AGE IN DECADES

	40-49 Yrs		50-59 Yrs		60-69 Yrs		70 Yrs and Above	
	Veg N=13	Non-veg N=8	Veg N=14	Non-veg N=12	Veg N=10	Non-veg N=8	Veg N=6	Non-veg N=8
Age (yr)	44.8	43.0	53.2	55.0	64.3	65.8	81.2	74.8
Weight (lb)	139.0	149.1	143.9	145.2	132.6	139.0	128.7	131.0
Height (in)	64.1	65.1	64.2	64.4	62.5	62.1	62.1	61.8
Bone Density								
Radius (g/cm^2)	0.75	0.76	0.72	0.70	0.60	0.64	0.56	0.55
Ulna (g/cm^2)	0.77[1]	0.76	0.76[2]	0.74	0.63[3]	0.65	0.49[4]	0.60
Finger (g/cc)	1.26	1.30	1.21	1.28	1.00	1.09	0.83	0.98
Nutrient Intakes								
Food								
Calcium (mg)	1173	869	1100	771	886	757	705	732
Phosphorus (mg)	1508	1177	1362	1107	1216	1121	1025	1047
Ca: P Ratio	0.77	0.72	0.75	0.68	0.71	0.67	0.71	0.70
Food Plus Supplements								
Calcium (mg)	1198	1086	1238	771	1044	762	705	732
Phosphorus (mg)	1508	1244	1427	1107	1216	1121	1025	1047
Ca: P Ratio	0.78	0.83	0.78	0.68	0.81	0.67	0.71	0.70

[1] N = 6

[2] N = 8

[3] N = 5

[4] N = 4

TABLE 4

REGRESSION COEFFICIENTS OF PHYSICAL MEASUREMENTS AND NUTRIENT INTAKES ON AGE IN VEGETARIAN AND NON-VEGETARIAN SUBJECTS

	Regression Coefficient[1, 2]	
	Vegetarians (N=43)	Non-vegetarians (N=36)
Weight (lb)	-0.495	-0.519
Height (in)	-0.087[3]	-0.105[3]
Bone Density		
Radius (g/cm^2)	-0.061[4]	-0.068[4]
Ulna (g/cm^2)	-0.075[4, 5]	-0.052[4]
Finger (g/cc)	-0.019[4]	-0.113[4]
Nutrient Intakes		
Food		
Calcium (mg)	-99.6	-48.3
Phosphorus (mg)	-91.4	-45.5
Ca: P Ratio	-0.02	-0.01
Food Plus Supplements		
Calcium (mg)	-90.8	-98.6[3]
Phosphorus (mg)	-96.9	-61.1
Ca: P Ratio	-0.01	-0.04

[1]Change per decade.

[2]None of the differences in the slopes of the regression lines between vegetarians and non-vegetarians were statistically significant, $P>0.05$.

[3]Significant at $P<0.05$; regression coefficients without superscripts were not significant ($P>0.05$).

[4]Significant at $P<0.0005$.

[5]N = 23.

The mean daily intakes of calcium (Veg = 1017 mg; Non-veg = 784 mg) and of phosphorus (Veg = 1325 mg; Non-veg = 1114 mg) from food alone were significantly greater ($P<0.05$) in the Veg than in the Non-veg group (Table 1). Of the 43 vegetarian subjects, 7 ingested calcium supplements ranging from 10 to 1732 mg per day with a mean value of 89.1 mg. A phosphorus supplement of 905 mg per day was ingested by 1 subject. Calcium supplements of 600 and 1350 per day were ingested by 2 of the 36 non-vegetarian subjects. One non-vegetarian subject ingested a phosphorus supplement of 605 mg. The mean intake from food plus supplements of calcium (Veg = 1106 mg; Non-veg = 838 mg) did not differ significantly between groups ($P>0.05$). There was a significantly greater intake of food plus supplemental calcium (Veg = 1106 mg; Non-veg = 838 mg) and food plus supplemental phosphorus (Veg = 1346 mg; Non-veg = 1131 mg) in the Veg than in the Non-veg group. The calcium to phosphorus ratios from food (Veg = 0.74; Non-veg = 0.70) and from food plus supplements (Veg = 0.78; Non-veg = 0.72) were not significantly different between groups.

When adjusted for age (mean age of both groups 57.9 years), the differences in the intakes of phosphorus from food and from food plus supplements between Veg and Non-veg groups were statistically significant (Table 2). There was also a statistically significant difference in the intakes of food calcium and food phosphorus between Veg and Non-veg groups when adjusted for age. Differences in the intakes of calcium from food plus supplements adjusted for age between groups approached significance ($P<0.06$).

There was no statistically significant difference in the food and food plus supplemental calcium to phosphorus ratio between Veg and Non-veg groups when adjusted for age.

Table 3 presents the calcium, phosphorus, and calcium to phosphorus ratios from food and from food plus supplements in vegetarian and non-vegetarian subjects by age in decades. There was a tendency for a decrease in the intakes of dietary calcium and phosphorus from food, and in the intake of food plus supplemental calcium and phosphorus, but generally not in the calcium to phosphorus ratios. There was also a tendency for greater intakes of dietary and dietary plus supplemental calcium and phosphorus in the Veg than in the Non-veg group during each decade with the exception of those 70 years and above. The calcium to phosphorus ratios from food and from food plus supplements tended to be greater in the Veg than in the Non-veg group during each decade except for the food plus supplemental calcium to phosphorus ratio during the fifth decade.

Table 4 presents the change in the food and food plus supplemental intakes of calcium, phosphorus, and their ratios per decade as calculated by regression analyses. There were no significant relationships between age and the intakes of calcium, phosphorus, or their ratio from food, or food plus supplemental calcium, phosphorus, or their ratio within the 2 groups ($P \geq 0.05$) with the exception of the food plus supplemental intake of calcium and age in the Non-veg group ($P < 0.05$). There were no significant differences in the decreases in nutrient intakes per decade between the Veg and Non-veg groups.

The mean bone density of 0.68 g/cm^2 of the radius in the vegetarian subjects did not differ significantly from that of 0.67 g/cm^2 in the non-vegetarian subjects (Table 1). Bone densities of the ulna (Veg = 0.69 g/cm^2; Non-veg = 0.69 g/cm^2) and the finger (Veg = 1.12 g/cc; Non-veg = 1.18 g/cc) also were not significantly different between groups. Due to instrumentation problems, bone density readings of the ulna were obtained on only 23 of the 43 vegetarian subjects. When adjusted for age, there were no significant differences in the bone densities of the radius, ulna, and finger between the Veg and Non-veg groups (Table 2). The values adjusted for age did not differ significantly from those unadjusted for age.

The mean values indicate a decrease in bone densities of the radius, ulna, and finger per decade in the Veg and Non-veg groups (Table 3). However, the data also indicate no differences in the decreases in bone densities with age between the 2 groups.

The change per decade in bone density of the radius (Veg = -0.061 g/cm^2; Non-veg = -0.068 g/cm^2), of the ulna (Veg = -0.075 g/cm^2; Non-veg = -0.052 g/cm^2), and of the finger (Veg = -0.019 g/cc; Non-veg = -0.113 g/cc) as calculated by regression analyses is presented in Table 4. There were significant negative correlations between age and bone densities of the radius and of the ulna ($P<0.0001$) in both groups. Bone density of the finger and age were also highly correlated in a negative direction in the Veg ($P<0.0001$) and in the Non-veg ($P<0.0004$) groups. There was no significant difference in the decrease in bone densities with age between groups as indicated

by the nonsignificant difference in the slopes of the regression lines.

Table 5 presents the change in bone density of the radius (g/cm^2) per unit change in height (inches) and weight (pounds). In both the Veg and Non-veg groups, there were significant positive correlations between bone density and height and also between bone density and weight. When adjusted for age, bone density of the radius was not significantly related to height or weight in either group. There were no statistically significant differences in the slopes of the regression lines for bone density of the radius and height or weight between the Veg and Non-veg groups.

The change in bone density of the radius (g/cm^2) per unit change in the intakes of calcium, phosphorus and their ratios from food and food plus supplements unadjusted and adjusted for the influence of age are also presented in Table 5. In the Veg group, bone density of the radius was not significantly related to the intakes of calcium from food, the calcium to phosphorus ratio from food, or the intakes of food plus supplemental calcium, food plus supplemental phosphorus or their ratio. Bone density of the radius was positively related to the intake of phosphorus from food ($P<0.05$). There was a significant positive relationship between bone density of the radius and the intakes of calcium and phosphorus from food in the Non-veg group ($P<0.05$). The relationships between bone density of the radius and the intakes of food plus supplemental calcium and phosphorus and their ratio were also significant in the Non-veg group ($P<0.05$). There were no statistically significant differences in the

TABLE 5

REGRESSION AND PARTIAL REGRESSION COEFFICIENTS OF BONE DENSITY OF RADIUS (g/cm^2) ON HEIGHT, WEIGHT, AND NUTRIENT INTAKES IN VEGETARIAN AND NON-VEGETARIAN SUBJECTS

	Regression Coefficients				Significance of Differences[1]	
	Vegetarians (N=43)		Non-vegetarians (N=36)			
	b[2]	b'[3]	b[2]	b'[3]	b	b'
Weight (lb)	0.00108[4]	0.00045	0.00212[4]	0.00120	N.S.	N.S.
Height (in)	0.01645[4]	0.00459	0.02804[4]	0.01299	N.S.	N.S.
Nutrient Intakes						
Food						
Calcium (mg)	0.00005	0.00002	0.00021[4]	0.00012	N.S.	N.S.
Phosphorus (mg)	0.00007[4]	0.00003	0.00016[4]	0.00010	N.S.	N.S.
Ca: P Ratio	0.05896	-0.01933	0.33225	0.19933	N.S.	N.S.
Food Plus Supplements						
Calcium (mg)	0.00002	0.00000	0.00013[4]	0.00007	Sign.	N.S.
Phosphorus (mg)	0.00006	0.00002	0.00017[4]	0.00009	N.S.	N.S.
Ca: P Ratio	-0.01667	-0.02548	0.25353[4]	0.11771	Sign.	N.S.

[1] Comparison of values between vegetarian and non-vegetarian subjects.

[2] Regression coefficients on nutrient intakes.

[3] Partial regression coefficients on nutrient intakes and age.

[4] Statistically significant, $P<0.05$; other regression coefficients were not statistically significant, $P>0.05$.

slopes of the regression lines for bone density of the radius and dietary calcium, phosphorus, and the calcium to phosphorus ratio, or dietary plus supplemental phosphorus between Veg and Non-veg subjects ($P>0.05$). The difference in the slopes of the regression lines for food plus supplemental calcium and the food plus supplemental calcium to phosphorus ratio between Veg and Non-veg groups was statistically significant ($P<0.05$).

When adjusted for the influence of age on bone density, there was no significant relationship between bone density of the radius and food or food plus supplemental calcium, phosphorus, and their ratios in both groups ($P>0.05$). However, the correlation between bone density of the radius and dietary calcium in the Non-veg subjects approached significance ($P<0.06$). There was no difference in the slopes of the regression lines for food and food plus supplemental calcium, phosphorus, and their ratio between the 2 groups.

CHAPTER V

DISCUSSION

The mean heights of 63.5 inches for both the vegetarian and non-vegetarian subjects (hereafter designated Veg and Non-veg, respectively) were less than that of the RDA reference woman, i.e., 65 inches (42). The mean weights of 138 pounds for the Veg and 142 pounds for the Non-veg groups exceeded that of 128 pounds for the RDA reference woman (42) but closely corresponded to that reported by Hardinge and Stare (39) for vegetarian and non-vegetarian subjects. In the present study, the differences in height and in weight between the Veg and Non-veg groups were not statistically significant, adjusted or unadjusted for age ($P>0.05$). Ellis et al. (36) and Hardinge and Stare (39) reported a tendency for vegans to be smaller in height and weight than non-vegetarians. There was a significant decrease in height with age but not weight with age in both groups of subjects in the present study, but the differences in the regression coefficients were not significant between groups.

The mean intake of calcium from food and from food plus supplements in the Veg group surpassed the RDA of 800 mg (42). This finding agrees with the report of Hardinge and Stare (39), and that of Mirone (43), but not with that by Brown and Bergen (34). Although the percent of calcium from milk and cheese was not determined in the present study, Hardinge and Stare (39) reported a greater consumption of milk and cheese in vegetarian than in non-vegetarian subjects. In the Non-veg

group of the present study, the mean intake of calcium exceeded the RDA only when calcium supplements were ingested. Justice et al. (54) reported that in institutionalized women 64 years and older, the mean calcium intake from the diet without supplements did not meet the RDA. Mason et al. (6) reported about 63 percent of the females ranging in age from 3 to 90 years exceeded the RDA for calcium. As is commonly reported, the phosphorus intakes from food and from food plus supplements in both groups of the present study exceeded the RDA (39, 43). The results indicated a decrease in food and food plus supplemental calcium and phosphorus with age although the tendency was not significant.

Hardinge and Stare (39) reported greater intakes of calcium and phosphorus in vegetarian than in non-vegetarian subjects. This is in agreement with findings of the present study in which the Veg group generally consumed significantly greater amounts of calcium and phosphorus from food and from food plus supplements than the Non-veg group, unadjusted for age. There were also significantly greater intakes of food calcium and food phosphorus adjusted for age, and food plus supplemental phosphorus adjusted for age ($P<0.05$). The difference in the food plus supplemental calcium between the Veg and Non-veg groups was significant at the $P<0.06$ level.

The calcium to phosphorus ratios of 0.74 from food and 0.78 from food plus supplements in the Veg group were not significantly different from the ratios of 0.70 from food and 0.72 from food plus supplements in the Non-veg group. Calcium to phosphorus ratios of 0.89 (39), 0.50 (34), and 0.78 (43) for vegetarians and 0.63 (39) for non-vegetarians

were calculated from the intakes reported in previous studies (39). Calcium to phosphorus ratios from food and from food plus supplements for Veg and Non-veg groups exceeded that of the 0.36 calcium to phosphorus ratio cited by Henrikson (44) for the average American diet.

The results from the present study support the well documented phenomenon of the loss of bone with age (1, 2, 7). Odland et al. (3) reported a loss of bone density of the finger after age 50 years. Their mean bone density values of the finger by age in decades made using the same instrument as 1 of those employed in the present study are lower than those obtained for both the Veg and Non-veg groups in the present study. However, the rate of loss which can be calculated from their cross-sectional data closely corresponded to the loss of bone density of the finger (0.119 g/cc per decade) in the Veg group and in the Non-veg group (0.113 g/cc per decade).

In the present study there was no significant difference in the bone density measurements between the Veg and Non-veg groups, adjusted or unadjusted for age. Ellis et al. (45), however, reported a significantly greater bone density in vegetarians than in omnivores. In the present study, there were no significant differences in the change in bone densities with age between the Veg and Non-veg groups.

In both the Veg and Non-veg groups, there was a significant negative correlation between bone density of the radius and height and also between bone density of the radius and weight. However, when adjusted for the influence of age, these correlations were not statistically significant. Garn et al. (2) reported a lower rate of age associated bone loss in tall subjects than in those of small or medium stature.

In the present study, there was also no significant difference in the slopes of the regression lines of bone density on height and bone density on weight between Veg and Non-veg groups unadjusted and adjusted for age.

A significant positive relationship between the intakes of calcium from both food and food plus supplements and bone density of the radius was obtained in the Non-veg group of the present study. This agrees with findings by some investigators (11, 55, 56), but not with those of others (15, 54, 57). In the present study, both bone density and calcium intake decreased with age (although the decrease in calcium with age was not statistically significant) so that when the effect of age was removed, there was no significant relationship between food and food plus supplemental calcium and bone density in both the Veg and Non-veg groups. There was a significant relationship between the intake of phosphorus from food and bone density in both the Veg and Non-veg group unadjusted for age but not when adjusted for age. However, in animals, it has been shown that phosphate supplementation resulted in resorption of bone (16, 18).

Several investigations with experimental animals have shown that a low calcium to phosphorus ratio in the diet (less than 2:1), regardless of how achieved, results in a pronounced loss of bone via a parathyroid-hormone mediated mechanism (22, 23, 24, 25). It has also been suggested that a high phosphorus diet resulting in a low calcium to phosphorus ratio may contribute to bone resorption in man (58). A calcium to phosphorus ratio of about 1:3 in the average American diet has been cited by Krook (27) as a factor in the occurrence of

periodontal disease which he proposed to be an initial manifestation of generalized osteoporosis. In the present study, a significant positive relationship between the calcium to phosphorus ratio in the diet and bone density of the radius was obtained only in the food plus supplemental calcium to phosphorus ratio unadjusted for age in the Non-veg group. The mean calcium to phosphorus ratios from food and food plus supplements in both the Veg and Non-veg groups (ranging from 0.70 to 0.78) were greater than those cited by Krook (27). It appears that a calcium to phosphorus ratio of less than 0.70 is necessary to induce bone loss, if indeed the dietary calcium to phosphorus ratio has any significant effect on the loss of bone. Levels of serum phosphorus and calcium are inversely related only when the saturation point is reached. Since the serum normally is not saturated, it is possible that a dietary phosphorus level high enough to cause saturation was not obtained in the present study and therefore, the phosphorus intake, though greater than the intake of calcium, was not sufficient to cause hypocalcemia and thus parathyroid-hormone mediated bone loss.

Although the nutrient intakes of calcium and phosphorus from food, and calcium, phosphorus, and their ratio from food plus supplements were generally related to bone density of the radius in the Non-veg group, this was not true in the Veg group. However, there was no significant difference between the regression coefficients of bone density of the radius on most nutrient intakes between the Veg and Non-veg groups. When adjusted for age, there was no significant difference between bone density of the radius and the intakes of calcium and phosphorus and their ratio from food and from food plus

supplements in the Veg and Non-veg groups.

Under the conditions of this study, the results indicate that the single most important factor influencing bone density of humans is age and that other factors such as the intake of calcium and phosphorus, or their ratio are relatively unrelated to bone loss. It also appeared that there is no difference in the rate of bone loss with age between vegetarians and non-vegetarians. Since the intake of calcium and phosphorus tended to decrease with age and bone density was also negatively related to age, a low calcium or phosphorus intake may occur with a low bone density in the elderly but not necessarily be causally related to a low bone density. The data indicate that bone loss is a phenomenon primarily associated with the aging process.

CHAPTER VI

SUMMARY

The influence of age and the dietary intakes of calcium and phosphorus and their ratio on the bone density of vegetarians and non-vegetarian subjects were investigated.

The mean age of 57.1 years in the Veg group was not significantly different from that of 58.8 years in the Non-veg group ($P>0.05$). There was no significant difference in weight (Veg = 137.7 lb; Non-veg = 141.6 lb) and in height (Veg = 63.5 in; Non-veg = 63.5 in) between groups ($P>0.05$). Mean values for height and weight were not statistically different between the two groups when adjusted for the mean age of both groups (57.89 years). There was a significant decrease in height with age but not weight with age in the Veg and Non-veg groups. Differences in the decreased height with age and the decreased weight with age between the Veg and Non-veg groups were not statistically significant.

The mean calcium intake from food (1017 mg) and from food plus supplements (1106 mg) in the Veg group surpassed the RDA. The RDA for calcium was also met from food plus supplements (838 mg) but not from food alone (784 mg) in the Non-veg group. The phosphorus intakes from food and from food plus supplements in both groups were greater than the RDA. There was a negative but not significant correlation between calcium and phosphorus intakes and age in both groups ($P>0.05$). The Veg group generally consumed significantly greater amounts of calcium and phosphorus from food alone and from food plus supplements than did

the Non-veg group, unadjusted and adjusted for age. The calcium to phosphorus ratios from food (Veg = 0.74; Non-veg = 0.70) and from food plus supplements (Veg = 0.78; Non-veg = 0.72) unadjusted and adjusted for age were not significantly different between groups. No significant relationship between the calcium to phosphorus ratio and age in both groups was obtained.

There was no significant difference in the mean bone density measurements of the radius, ulna, and finger between the Veg and Non-veg groups unadjusted and adjusted for the mean age of both groups. A highly significant negative correlation between bone densities of the radius, ulna, and finger and age was obtained ($P<0.0005$). There was no significant difference in the slopes of the regression lines of bone density of the radius on age between Veg and Non-veg groups.

In both the Veg and Non-veg groups, there was a significant positive correlation between bone density of the radius and height, and also between bone density of the radius and weight. However, when adjusted for age, these correlations were not statistically significant. There were also no significant differences in the slopes of the regression lines of bone density on height and bone density on weight between Veg and Non-veg groups unadjusted and adjusted for age.

In the Veg group, the phosphorus intake from food alone was positively related to bone density of the radius. Regression coefficients on other nutrient intakes were nonsignificant in the Veg group. In the Non-veg group, there was a significant positive relationship between bone density and the intakes of calcium and phosphorus from food and also the intakes of calcium, phosphorus, and their ratio

from food plus supplements. When adjusted for the influence of age, however, there was no significant correlation between bone density of the radius and each of the nutrient intakes of both groups. The slopes of the regression lines for bone density on the calcium intake and the calcium to phosphorus ratio from food plus supplements were significantly different between groups. There were no significant differences between any of the regression lines of bone density on nutrient intake between Veg and Non-veg groups adjusted for age.

REFERENCES

REFERENCES

1. Wachmen, A., and Bernstein, D. S. (1968) Diet and osteoporosis. Lancet 1, 958-959.

2. Garn, S. M., Rohmann, C. G. and Wagner, B. (1967) Bone loss as a general phenomenon in man. Federation Proc. 26, 1729-1736.

3. Odland, L. M., Mason, R. L. and Alexeff, A. I. (1972) Bone density findings of 409 Tennessee subjects. I. Bone density considerations. Amer. J. Clin. Nutr. 25, 905-907.

4. Krishnaroa, G. V. C. and Draper, H. H. (1969) Age-related changes in the bones of adult mice. J. Gerontol. 24, 149-151.

5. Stewart, R. J. C., Sheppard, H. G., Preece, R. E. and Exton-Smith, A. N. (1972) Bone resorption in the elderly. Age and Aging 1, 1-13.

6. Mason, R. L., Odland, L. M. and Alexeff, A. I. (1968) Bone density and dietary findings in Cumberland County, Tennessee. Tenn. Farm and Home Science Progress Report 68, 5-7.

7. Newton-John, H. F. and Morgan, D. B. (1968) Osteoporosis: a disease or senescence? Lancet 1, 232-233.

8. Mazess, R. B. and Mather, W. (1974) Bone mineral content of North Alaskan Eskimos. Amer. J. Clin. Nutr. 27, 916-925.

9. Hegsted, D. M. (1967) Mineral intake and bone loss. Federation Proc. 26, 1747-1753.

10. Nordin, B. E. C. (1962) Calcium balance and calcium requirements in spinal osteoporosis. Amer. J. Clin. Nutr. 10, 384-390.

11. Caniggia, A. (1965) Medical problems in senile osteoporosis. Geriatrics 20, 300-311.

12. Nordin, B. E. C. (1961) The pathogenesis of osteoporosis. Lancet 1, 1011-1014.

13. Harrison, M., Fraser, R. and Mullan, B. (1961) Calcium metabolism in osteoporosis. Acute and long term response to increased calcium intake. Lancet 1, 1015-1019.

14. Henry, K. M., and Kon, S. K. (1953) The relationship between calcium retention and body stores of calcium in the rat: effect of age and of vitamin D. Brit. J. Nutr. 1, 147-149.

15. Dudl, R. J., Ensinck, J. W., Baylink, D., Chesnut, C. H., Sherrard, D., Nelp, W. B. and Palmieri, G. M. A. (1973) Evaluation of intravenous calcium as therapy for osteoporosis. Amer. J. Med. 55, 631-637.

16. Jowsey, J. and Balasubramaniam, P. (1972) Effect of phosphate supplements on soft-tissue calcification and bone turnover. Clin. Science 42, 289-299.

17. Thornton, P. A. (1974) Phosphate as a mediator of hypocalcemia development in chicks with low calcium intakes. Nutr. Reports Internat. 9, 183-190.

18. LaFlamme, G. H. and Jowsey, J. (1972) Bone and soft tissue changes with oral phosphate supplements. J. Clin. Invest. 51, 2834-2840.

19. Schryver, H. F., Hintz, H. F. and Craig, P. H. (1971) Calcium metabolism in ponies fed a high phosphate diet. J. Nutr. 101, 259-264.

20. Argenzio, R. A. (1974) Calcium and phosphate homeostasis in horses. J. Nutr. 104, 18-27.

21. Krook, L., Barrett, R. E., Usui, K. and Wolke, R. E. (1963) Nutritional secondary hyperparathyroidism in the cat. Cornell Vet. 53, 224-240.

22. Shah, B. G., Krishnarao, G. V. G. and Draper, H. H. (1967) The relationship of calcium and phosphorus nutrition during adult life and osteoporosis in aged mice. J. Nutr. 92, 30-42.

23. Draper, H. H., Ten-Lin, S. and Bergen, J. G. (1972) Osteoporosis in aging rats induced by high phosphorus diets. J. Nutr. 102, 1133-1142.

24. Krishnaroa, G. V. G. and Draper, H. H. (1972) Influence of dietary phosphate on bone resorption in senescent mice. J. Nutr. 102, 1143-1146.

25. Anderson, G. H. and Draper, H. H. (1972) Effect of dietary phosphorus on calcium metabolism in intact and parathyroidectomized adult rats. J. Nutr. 102, 1123-1132.

26. Krook, L. (1968) Dietary calcium-phosphorus and lameness in the horse. Cornell Vet. Suppl. 1, 59-73.

27. Krook, L. (1972) Human periodontal disease and osteoporosis Cornell Vet. 62, 371-391.

28. Kelly, P. J., Jowsey, J., Riggs, B. L. and Elveback, L. R. (1967) Relationship between serum phosphate concentration and bone resorption in osteoporosis. J. Lab. Clin. Med. 69, 110-115.

29. Reiss, E., Canterbury, J. M., Bercovitz, M. A. and Kaplan, E. L. (1970) The role of phosphate in the secretion of parathyroid hormone in man. J. Clin. Invest. 49, 2146-2149.

30. Ten-Lin, S., Draper, H. H. and Bell, R. R. (1974) Hypocalcemia, hyperparathyroidism and bone resorption in rats induced by dietary phosphate. J. Nutr. 104, 1195-1201.

31. Clark, I. (1969) Importance of dietary calcium: phosphorus ratios on skeletal calcium, magnesium and phosphorus metabolism. Amer. J. Physiol. 217, 865-870.

32. Newell, G. K. and Beauchene, R. E. (1975) Effects of dietary calcium level, acid stress, and age on renal serum and bone responses of rats. J. Nutr. 105, 1039-1047.

33. Erhard, D. (1973) The new vegetarians. Part 1--Vegetarianism and its medical concsequences. Nutr. Today 8, 4-12.

34. Brown, P. T. and Bergen, J. G. (1975) The dietary states of "new" vegetarians. J. Amer. Diet. Assoc. 67, 455-459.

35. Hardinge, M. G. and Crooks, H. (1963) Non-flesh dietaries. 1. Historical background. J. Amer. Diet. Assoc. 43, 545-549.

36. Ellis, F. R., Path, M. R. C. and Montegriffo, V. M. E. (1970) Veganism, clinical findings, and investigations. Amer. J. Clin. Nutr. 23, 249-255.

37. Ellis, F. R. and Montegriffo, V. M. E. (1971) The health of vegans. Pl. Fds. Hum. Nutr. 2, 93-103.

38. Kurtha, A. and Ellis, F. R. (1970) The nutritional, clinical and economic aspects of vegan diets. Pl. Fds. Hum. Nutr. 2, 13-22.

39. Hardinge, M. G. and Stare, F. J. (1954) Nutritional studies of vegetarians. 1. Nutritional, physical, and laboratory studies. Amer. J. Clin. Nutr. 2, 73-82.

40. Hardinge, M. G. and Crooks, H. (1964) Non-flesh dietaries. 3. Adequate and inadequate. J. Amer. Diet. Assoc. 45, 537-542.

41. Commentary. (1974) Vegetarian diets. J. Amer. Diet. Assoc. 65, 121-122.

42. National Research Council. Food and Nutrition Board. Recommended Dietary Allowances, 8th ed. National Academy of Sciences, Washington, D.C.

43. Mirone, L. (1954) Nutrient intake and blood findings of men on a diet devoid of meat. Amer. J. Clin. Nutr. 2, 246-251.

44. Henrikson, P. (1968) Periodontal disease and calcium deficiency. An experimental study in the dog. Acta. Odont. Scand., Suppl., 50, 1-128.

45. Ellis, F. R., Holish, S. and Ellis, J. W. (1972) Incidence of osteoporosis in vegetarians and omnivores. Amer. J. Clin. Nutr. 25, 555-558.

46. Meema, H. E. (1973) Photographic density versus bone density. Amer. J. Clin. Nutr. 26, 687.

47. Ellis, F. R., Holish, S. and Sanders. J. A. B. (1974) Osteoporosis in British vegetarians and omnivores. Amer. J. Clin. Nutr. 27, 769-770.

48. Adams, C. F. (1975) Nutritive Value of American Foods in Common Units. Agriculture Handbook No 456. U. S. Government Printing Office, Washington, D.C.

49. Watt, B. K. and Merrill, A. L. (19) Composition of Foods - Raw, Processed, Prepared. Revised. USDA Agric. Handbook No 8, U. S. Department of Agriculture, Washington, D.C.

50. Mason, R. L. and Ruthven, C. (1965) Bone density measurements in vivo: improvement of x-ray densitometry Science 150, 221-222.

51. Williams, D. E and Mason, R. L. (1962) Bone density measurements in vivo. Science 138, 39-40.

52. Barr, A. J. and Goodnight, J. H. (1972) Statistical Analysis System. Department of Statistics, North Carolina State University, Raleigh, N.C.

53. Steel, R. G. D. and Torrie, J. H. (1960) Principles and Procedures of Statistics, pp. 181-191, 73-76, McGraw-Hill Book Co., Inc., New York.

54. Justice, C. L., Howe, J. M. and Clark, H. E. (1974) Dietary intakes and nutritional status of elderly patients. J. Amer. Diet. Assoc. 65, 639-646.

55. Odland, L. M., Mason, R. L. and Alexeff, A. I. (1972) Bone density and dietary findings in 409 Tennessee subjects. II. Dietary considerations. Amer. J. Clin. Nutr. 25, 908-911.

56. Williams, D. E., McDonald, B. B., Morrell, E., Schofield, F. A. and MacLeod, F. L. (1957) Influence of mineral intake on bone density in humans and rats. J. Nutr. 61, 489-505.

57. Davidson, C. S., Livermore, J., Anderson, P. and Kaufman, S. (1962) The nutrition of a group of apparently healthy aging persons. Amer. J. Clin. Nutr. 10, 181-199.

58. McBean, L. D. and Speckmann, E. W. (1974) A recognition of the interelationships of calcium with various dietary components. Amer. J. Clin. Nutr. 27, 603-609.

APPENDIX

UNIVERSITY OF TENNESSEE - KNOXVILLE

TENNESSEE AGRICULTURAL EXPERIMENT STATION

Project Consent Form

I agree, as indicated by my signature below, that:

(1) I would like to participate in the Nutrition and Bone Density Project approved and administered by the professional staff of the Tennessee Agricultural Experiment Station and the College of Home Economics, University of Tennessee, Knoxville;

(2) I understand that this project has been judged by the profesional staff as not likely to be harmful to the participants involved or an inappropriate or unecessary invasion of the privacy of the families;

(3) I understand that participation in this program is not likely to harm me and that no specific benefits or effects as guaranteed other than information from the assessment of my bone density and nutrient intake;

(4) It is my understanding that each aspect of the project in which I am asked to participate will be explained to me and that I may withdraw from participation at any time if involvement is unacceptable to me;

(5) All results will be treated with strict confidence, all individuals will remain anonymous in reporting any results, and all results will be handled in a professional manner;

(6) The University of Tennessee, its agents and employees, are released from any liability resulting from such participation, irrespective of cause or effect.

By my signature, I indicate that the research has been explained to me in detail and that I understand that any further questions that I may have about the project will be answered for me by the project director or some other designated member of the project staff.

Signed: _____

Witness: _____

Date: _____

RMM/nke
1/76

NAME_____ EXPT. NO. _____

ADDRESS_____

DATE_____ DAY OF WEEK_____

	FOOD	KIND & STATE	AMOUNT
BREAKFAST			
BETWEEN MEALS			
NOON MEAL			
BETWEEN MEALS			
EVENING MEAL			
AFTER EVENING MEAL			

SUPPLEMENTS: VITAMIN____ MINERAL____ OTHER____ BRAND_____

DIETARY HISTORY

NAME_____ EXPT. NO._____DATE_____

ADDRESS_____

BIRTH DATE_____

VEGETARIAN_____ NON-VEGETARIAN_____ NUMBER OF YEARS_____

IF VEGETARIAN, DO YOU USE EGGS___, DAIRY PRODUCTS_____, FISH_____

SINGLE_____ MARRIED_____ NUMBER OF CHILDREN_____

ANY BROKEN BONES_____ AT WHAT AGE_____

MEDICATION_____

MEALS EATEN PER DAY: BREAKFAST _____ LUNCH_____ SUPPER_____ OTHER___

IF "OTHER", EXPLAIN_____

FOODS WELL LIKED AND EATEN OFTEN:

FOODS DISLIKED AND AVOIDED:

FOOD GROUPS - FREQUENCY OF SERVINGS

1. Bread and Cereals

   Bread: Whole grain_____ Enriched_____

   Cereals: Cooked_____ ready-to-serve_____ rice_____

   Number of servings per day_____

   Other: Pastas (macaroni, etc.)_____ pancakes, waffles, doughnuts, sweet rolls_____

   Number of servings per week_____

2. Milk and dairy products

   Milk: whole_____ 2%_____ skim_____ buttermilk_____

   evaporated_____ dry non-fat (reconst.)_____

Amount per day: 3 or more cups_____ 2-3 cups_____

0-2 cups_____ none_____

Cheese: cottage_____ cream_____ cheddar type_____

Number of servings per week_____

Other: yogurt_____ ice cream_____ ice milk_____

Number of servings per week_____

3. Fruits and Vegetables

Citrus fruits (including juice): Oranges_____ grapefruit_____

tangerines_____

Other juices: apple_____ cranberry_____ grape_____ pineapple_____

prune_____

Number of servings per day_____

Other fruits: apples_____ apricots_____ bananas_____ berries_____

grapes_____ pears_____ peaches_____

Number of servings per week_____

Vegetables: potato (white)_____ tomato, raw_____ tomato, canned_____

green leafy, raw_____ green leafy, cooked_____ green,

non-leafy, raw_____ green, non-leafy, cooked_____ deep

yellow, raw_____ deep yellow, cooked_____ other_____

Servings per day_____

4. Meat and Meat Alternates

Meat: beef_____ veal_____ lamb_____ pork_____ liver_____ fish_____

poultry_____ luncheon meats_____ other_____

Number servings per day_____

Alternates: eggs_____ dry beans_____ dry peas_____ lentils_____

nuts_____ peanuts_____ peanut butter_____ meat analogs_____

Number of servings per day_____

5. Miscellaneous

Fats and oils_____ butter or margarine_____ cookies_____

cake_____ molasses_____ syrup_____ candy_____ coffee_____

tea_____ cocoa_____ soft drinks_____ alcohol_____ tobacco_____

Frequency of use_____

UNIVERSITY OF TENNESSEE
NUTRITION RESEARCH
INSTRUCTION SHEET FOR RECORDING FOOD INTAKE

We would like a record of what you eat for _____ days.

Please read carefully the instructions below before you start to list the foods you have eaten.

Please record foods and snacks as they are eaten rather than trying to do a recall at the end of the day. If you need more space, use the back of this sheet.

1. WRITE DOWN EVERYTHING THAT YOU EAT

   If you miss a meal, write "nothing" in the space for that meal.

2. BE SURE TO WRITE DOWN THE KIND OF FOOD YOU EAT (KIND)

   Example: Cereal - Oatmeal, shredded wheat, conrflakes, etc.
   Bread - Whole wheat, white, rye; also commercial or homemade
   Meat - Roast beef, hamburger, veal steak, pork chops, etc.
   Salad - Head lettuce, canned fruit, tuna, cottage cheese, etc.
   Milk - Whole, 2%, skim, canned, etc.

3. DESCRIBE SPECIFICALLY HOW EACH FOOD IS PREPARED (STATE)

   Example:

Egg	- fried, boiled, scrambled, etc.
Meat	- broiled, breaded, fried, baked, etc.
Fruits and vegetables	- fresh, frozen or canned
Vegetables	- creamed, buttered, mashed, baked, etc.

   If food is not cooked, but eaten raw, write "RAW"

4. WHEN DIFFERENT FOODS ARE COMBINED WRITE DOWN EACH FOOD INCLUDED AND THE AMOUNT OF EACH FOOD

   Example:

Raw Salad		Cheese Sandwich	
lettuce	1 leaf	bread	2 slices
tomato	1 slice	cheddar cheese	1 slice
cucumber	2 slices	lettuce	1 leaf
french dressing	1 tablespoon	mayonnaise	2 teaspoons

5. WHEN YOU EAT OTHER COMBINATION FOODS, SUCH AS CASSEROLE DISHES, SOUPS, STEWS, PUDDINGS, ETC., WRITE DOWN THE INGREDIENTS IF HOMEMADE OR SIMPLY THE BRAND NAME IF A CONVENIENCE OR STORE-BOUGHT ITEM IS USED.

   Example: Soup - Campbell's Tomato

6. WRITE DOWN THE AMOUNT OF EACH FOOD YOU EAT. Use a standard measuring cup, teaspoon or tablespoon, and a ruler to "measure" your food. Write down how many level teaspoons (t), tablespoons (T) you eat or whether you eat 1/2 or 1/3 or 1 cup, etc. Write down the number of slices or pieces. For Example: pineapple, canned, 1 slice or apple, raw, 1 whole. Do not write down "glasses," "bowls," or "plates" for any foods such as milk, soup, vegetables, etc. Use the utensils provided to determine the amount.

   Example: Soup - Campbell's Tomato 1 cup

   The ruler should be used for foods that can not be measured with a measuring cup, teaspoon or tablespoon. Some examples are cake, meat, pancakes, pies, etc. For foods with a round shape such as rolls, pancakes, meat patties, cupcakes, etc., the diameter and thickness should be measured. For all other shapes, length, width and thickness should be measured.

   Example:

pancake	-	1-8" diameter, 1/4 1/4 thick
choc. cake		iced, 1 piece, 2" x 3" x 1"
baked ham		1 slice, 4" x 3" x 1/4"
pie		give measurements in inches, or tell whether it is a 1/4th or 1/8th etc. of a 8", 9" pie (diameter of whole pie)

7. BE SURE TO WRITE DOWN THE FOODS YOU ADD TO OTHER FOODS AND THE AMOUNT SUCH AS THE SUGAR, CREAM, OR BUTTER YOU USE.

   Example: the amount of sugar or cream used on cereal, fruit or in tea and coffee
   the amount of butter on vegetables or bread
   the amount of jelly on toast or syrup on pancakes

   Remember to record in level teaspoons or tablespoons; then if you want more, take it, just remember to add that amount too.

   SAMPLE RECORDINGS:

FOOD	KIND AND STATE	AMOUNT
cereal	oatmeal	3/4 cup
sugar	- - - -	2 teaspoons
cream	half and half	1/4 cup
pancake	Hungry Jack Pancake Mix	1, 6" diam. 1/4" thick
egg	fried	1 large
meat	baked ham	4" x 2" x 1"
potatoes	mashed	3/4 cup
peas	canned	1/2 cup
butter on peas	- - - -	1/2 teaspoon
milk	whole	1 cup
cake	choc., iced	2" x 2" x 1"

8. LIST AMOUNT AND BRAND OF ANY VITAMIN/MINERAL SUPPLEMENTS YOU TAKE.

9. IF YOU HAVE QUESTIONS, PLEASE DO NOT HESITATE TO CALL MRS. MASON OR DR. BEAUCHENE AT 974-3491.

VITA

Teresa Ann Davis was born in Middlesboro, Kentucky on March 23, 1955. She attended elementary school in Claiborne County, Tennessee and was graduated from Powell High School, Powell, Tennessee in June 1971. The following September she entered The University of Tennessee, Knoxville, and in August 1975, she received her Bachelor of Science degree in Home Economics Education. She entered the Graduate School of The University of Tennessee in the Fall of 1975 and served as a graduate assistant in the Department of Food Science, Nutrition, and Food Systems Administration. In August 1976, she received the Master of Science degree with a major in Nutrition.