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Relationships between Bone Density and Dietary Intakes of Energy and Protein in Older Female Vegetarians and Nonvegetarians

Mary Elizabeth Kunkel
University of Tennessee, Knoxville

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To the Graduate Council:

I am submitting herewith a thesis written by Mary Elizabeth Kunkel entitled "Relationships between Bone Density and Dietary Intakes of Energy and Protein in Older Female Vegetarians and Nonvegetarians." 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.

Roy E. Beauchene, Major Professor

We have read this thesis and recommend its acceptance:

Ada Marie Campbell, Rossie L. Mason

Accepted for the Council:

Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)
To the Graduate Council:

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[Signature]
Roy A. Beauchene
Major Professor

We have read this thesis and recommend its acceptance:

[Signature]
Ada Marie Campbell

[Signature]
Rose L. Mason

Accepted for the Council:

[Signature]
Vice Chancellor
Graduate Studies and Research
RELATIONSHIPS BETWEEN BONE DENSITY AND DIETARY INTAKES OF ENERGY AND PROTEIN IN OLDER FEMALE VEGETARIANS AND NONVEGETARIANS

A Thesis
Presented for the Master of Science Degree
The University of Tennessee, Knoxville

Mary Elizabeth Kunkel
August 1976
ACKNOWLEDGMENT

This thesis was made possible by the hard work of many people. I want to thank them all and to give special thanks to the following people:

Dr. Roy E. Beauchene for his patience and guidance in the writing of this thesis;

Rossie L. Mason for her unfailing enthusiasm and expertise in conducting the research;

Dr. Ada Marie Campbell for serving on the thesis committee;

Dr. W. L. Sanders for assistance with the statistical analyses;

Teresa Davis for sharing the project;

Susie Bredderman, June Sanders, Minda Lazarov, and Linda Kunkel for their help in compiling the data;

And all the women who were subjects in the study.

While not directly involved in the research, my family and friends deserve special credit for their love and assistance.

Finally, but especially, I want to thank Dr. Sue Thompson of the University of Central Arkansas for her encouragement and stimulation of my interest in nutrition.
The purposes of this study were to compare differences in bone density, height, and weight among female vegetarians and nonvegetarians and to determine significant relationships between the physical measurements and dietary intake of calories and protein.

After obtaining informed consent, complete data were collected on 43 vegetarians and 36 nonvegetarians. Height, weight, and bone density measurements were taken. Dietary information was obtained from 7-day dietary records and diet histories. Dietary supplements were also recorded.

Daily intakes of calories, protein, and fat were calculated by computer using the food values in USDA Handbook No. 8. Percent of the total calories coming from protein and fat were also computed. Bone density values of the phalanx 5-2 were determined using an instrument developed by the Department of Nutrition, University of Tennessee, Knoxville. Bone mineral content of the radius was determined using a Norland-Cameron bone mineral analyzer.

The 2 groups of women showed remarkable similarities. Mean age of the vegetarians was 57.1 years while the nonvegetarians averaged 58.8 years of age. Mean height, weight, bone density index of the phalanx 5-2, and bone mineral content of the radius for the vegetarians were 63.46
inches, 137.7 pounds, 1.12 g/cc, and 0.68 g/cm$^2$, respectively. Corresponding values for the nonvegetarians were 63.49 inches, 141.6 pounds, 1.18 g/cc and 0.67 g/cm$^2$.

Dietary factors also showed similarities. Energy intake was 1600 kcal for the vegetarians and 1578 kcal for the nonvegetarians. Daily protein intake among the vegetarians was 64.6 g or 16.2% of total calories; that of the nonvegetarians was 66.6 g or 17.0%. Mean fat intakes of the 2 groups were significantly different ($P < 0.05$). The vegetarians averaged 57.2 g or 31.7% of calories and the nonvegetarians averaged 62.6 g or 35.5% of calories as fat per day.

Adjusting mean values of the parameters studied to the mean age of both groups, 57.9 years, showed percent of calories coming from fat to be the parameter that differed significantly between the groups ($P < 0.01$). Placing the subjects into groups by 10-year age intervals showed a tendency for all physical measurements and dietary factors to decrease with age.

The per decade decrease in the parameters studied was calculated from regression equations. Height, bone density index of the phalanx 5-2, and bone mineral content of the radius decreased significantly ($P < 0.01$) with age. Fat intake and percent of the calories as fat also decreased significantly ($P < 0.05$). The simple regressions between the 2 groups did not differ significantly. In multiple
regression, the slopes differed significantly ($P < 0.05$) for bone mineral content of the radius regressed on age, caloric intake, and protein intake holding any 2 of the variables constant. The slopes also differed significantly when bone mineral content of the radius was regressed on age holding weight, height, and the intakes of protein and energy constant.

Simple linear regression showed age to be significantly negatively related ($P < 0.01$) to bone mineral content of the radius of both groups. Positive relationships were found among both groups between bone mineral content of the radius and weight, height, and protein intake. Among the vegetarians there was also a positive relationship between bone mineral content of the radius and total caloric intake, fat intake and percent of calories coming from fat. Multiple regression analysis showed age to be the factor with the greatest effect on bone density. Significant negative relationships between bone density and age were found in both groups. In the nonvegetarians, positive relationships were obtained between bone mineral content and protein intake, holding age, weight, height, and caloric intake constant; and between bone mineral content and weight when age, protein intake, caloric intake, and height were held constant.
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CHAPTER 1

INTRODUCTION

Virtually all populations experience bone demineralization with aging. The pathological condition associated with the decrease in bone mass is called osteoporosis, which is apparently the predominant form of bone loss in the adult. For reasons that are not clear, women are more frequently affected. Populations differ mainly in the degree of severity and time of onset of this phenomenon. The pathogenesis of the condition is generally regarded as idiopathic with some causative factors possibly related to diet.

High protein diets have been found to result in negative calcium balances which, if continued for long periods of time, may affect bone mass. Studies done on populations that consume high protein diets noted an accelerated rate of bone loss of early onset; vegetarians, who tend to have lower protein intakes, may have a slower rate of bone loss.

Vegetarianism is becoming increasingly popular among all age groups in this country. The major types of vegetarians are lacto-ovo-vegetarians who consume eggs and milk and vegans who consume no animal products. While apparently nutritionally adequate, lacto-ovo-vegetarian diets have not been extensively studied in terms of their effect on the rate of bone demineralization.
The purpose of this study was to compare protein and calorie levels of vegetarian and nonvegetarian diets as to their effect on the physical measurements of height, weight, and bone density among older females.
CHAPTER 2

REVIEW OF LITERATURE

The term osteoporosis, a nebulous word in itself, is used to describe a condition whose etiology, symptoms, and treatments are equally nebulous. It is generally defined as the condition of the skeleton or a part of the skeleton in which the bone present is decreased in amount but normal in composition (1,2). Since diagnostic criteria vary, the prevalence of osteoporosis depends on its definition and the nature of the population under study (3), but it is generally agreed that the decrease in bone density is an ubiquitous age-related phenomenon occurring in both sexes (1,3-6). The disorder may be found in as many as 30% of people over age 65 (7). Harris and Heaney (1) point out that the true figures are probably even higher due to the difficulties in the early detection of bone loss.

The fact that osteoporosis occurs about 4 times more frequently in females than in males (7,8) might be explained by the facts that females lose bone at a more rapid rate and have only 75% of the bone mass of males at maturity; therefore, a given loss in the female would have a greater relative effect on bone mass than a comparable loss in the male (9).

Natural bone dissolution throughout adulthood is of sufficient consequence that the age-specific fracture rate
doubles every 5 years after the middle of the fourth decade (10). Vose and Kubala (11) found an exponential relationship between breaking stress and average ash content of dried, embalmed human femurs indicating that as ash content of bone decreased, the ability to withstand stress also decreased. This decreased bone density and increased bone fragility accompanying aging may explain a large number of the spontaneous fractures among the elderly. Iskrant and Smith (12) estimated that of the 1,000,000 fractures experienced each year by women 45 years and over, about 700,000 are incurred by osteoporotics whose fracture rates are about twice as high as nonosteoporotics of the same age group.

Cross-sectional studies by Newton-John and Morgan (2) and Lutwak (13) indicated that bone loss occurred at a constant rate in all populations and that the only difference between groups that manifested osteoporosis and those that did not was the level of bone mass at maturity. In longitudinal studies, Adams et al. (3) and Smith et al. (14) reported increasing variances in bone mass between and within sexes with age indicating that bone loss is not uniform.

The presence of osteoporosis indicates an imbalance between the processes of bone formation and bone resorption (1,3,10,15-17). Bone formation involves the deposition and calcification of organic matrix; bone resorption involves the breakdown and solubilization of bone components (18). While
the rates of bone formation and resorption in osteoporotics may be normal per unit of body mass, when computed per unit of bone mass, both are elevated. Normally, bone resorption increases at the same rate on all bone surfaces. Since trabecular bone has a greater surface area than cortical bone, it is more readily resorbed (3). Such preferential resorption may account for the collapsed vertebrae often found among osteoporotics. Cortical bone is affected by a concomitant periosteal deposition and endosteal resorption resulting in an enlargement and thinning of the cortex. The expanded shaft will absorb less stress and therefore breaks more easily (1).

The etiology of osteoporosis is unknown but is probably a composite of many factors. It has been attributed to various dietary (5,19-22) and hormonal deficiencies (3,9,15,19,21,23) and to inactivity (13,15,24).

While bone loss is a universal phenomenon, it seems to occur with greater frequency among certain populations. Canadian and Alaskan Eskimos have been reported to have an accelerated rate of bone loss of earlier onset than that observed in white populations (25-29). In a controversial study (30) comparing bone densities of vegetarians and omnivores, Ellis et al. (31,32) noted a greater, but not significantly different, bone density among vegetarian females under age 65. One major difference between the diets of these 2 groups is the protein source.
In all diets the quality and quantity of protein are of great concern. Protein quality is generally regarded as being dependent on the amounts and utilisability of the indispensable amino acids present. Quality of protein from plant sources is generally lower than that from animal sources (33-35). However, judicious mixing of plant foods can give protein combinations of about the same nutritional value as animal proteins (33-37).

The recommended daily allowance of mixed protein is 0.8 g per kg of body weight per day which is equivalent to 56 g for a 70 kg man and 45 g for a 56 kg woman (38). Intakes of most groups exceed this figure; the protein intakes of lacto-ovo-vegetarians have been found to range from 65.5 g (39) to 82 g (40) per day. The intakes of Eskimos, in times of meat availability, range from 200-400 g per day (27).

Wachman and Bernstein (41) considered bone dissolution as "a possible mechanism to buffer the fixed acid load imposed by the ingestion of acid ash in man." In the steady state acid can be produced during the oxidation of sulfur, the oxidation of the cations neutralizing phosphate diesters, or the production of organic acids from neutral foodstuffs (42). Chronic metabolic acidosis is regularly accompanied by hypercalciuria (28,43). Since bone contains 99% of the body's calcium, prolonged hypercalciuria could result in bone loss (44).
Newell and Beauchene (45) acid-stressed rats by feeding them ammonium chloride. They found that acid stress increased urinary calcium and phosphorus excretion but that the bones were unaffected. Barzel (46-48) reported that NH₄Cl administration caused development of osteoporosis in rats of both sexes. In female rats neither sensitivity to the acid nor increased bone loss resulted from the removal of the ovaries. A decreased bone calcium has also been noted in diabetic and normal rats following NH₄Cl administration (49). Lemann et al. (50) administered NH₄Cl to adult human males and noted a net positive acid balance implicating involvement of the alkaline bone salts. Garnett et al. (51) noted a mean daily loss of 560 mg of calcium in obese patients during the acidotic state induced by total starvation.

The ingestion of animal proteins, a source of acid ash, can tend to create an acidotic condition in animals and humans (22). Most of the work done on the effect of varying protein intake on bone has utilized young animals (52-61). In these studies, either very high or very low protein intakes resulted in osteoporotic development. However, these results cannot necessarily be carried over to adult animals. For example, if protein deficiency induces osteoporosis in growing animals by decreasing osteoblastic activity, the effect of the deficiency as a cause of osteoporosis could be expected to decrease with the level of osteoblastic activity; e.g., with
maturation (16). With adult animals, the effect of increased protein intake is less consistent, perhaps reflecting differences in requirements for maintenance. Methfessel and Spencer (62) noted that with increases in dietary protein or calcium, urinary and fecal calcium excretion increased accompanied by decreased calcium absorption and uptake by the femur. Bell et al. (63) and Moore et al. (64) did not note bone demineralization in adult animals fed high protein diets either deficient or adequate in calcium.

Studies on humans have noted hypercalciuria associated with high levels of protein intake (65-72). With high protein intakes, some investigators reported a decrease in fecal calcium (65-67), others noted an increase in fecal calcium (69-72), and another indicated maintenance of previous fecal calcium levels (68). Bone mineral measurements were not made in these studies. While Smith et al. (73) found osteoporotics to have significantly lower protein intakes, deCosta and Moorhouse (74) did not find a correlation between protein intakes and bone thickness in the elderly.

The calcium loss frequently associated with a high animal protein intake could account for both the accelerated bone loss among Eskimos (25-29) and the greater bone density among vegetarians (31,32). Based on balance studies in whites (66,67,70,72), the level of protein intake noted among Eskimos could cause a calcium loss of 100 mg or more per day
or 365 g per decade. Such a loss is much more than actually noted indicating adaptation to high protein intakes. In addition occasional periods of starvation or ketoacidosis might increase calcium loss (51). Whether the greater bone density of the vegetarians was due to the acid ash of protein or to other differences was not determined (31).

Caloric intake is another dietary factor that may be of importance in the development of osteoporosis although the mechanism of its effect is not as well understood as that of protein. Justice et al. (75) and Exton-Smith et al. (76) found no correlation between caloric intake and bone density in elderly females. Indirectly related, Whitfield (77), Saville and Nilsson (78), and Smith et al. (73) found significant relationships between bone density and height and weight. Other studies have correlated bone thickness with skin thickness (79), subcutaneous fat (80), and muscle weight (24).

While relationships to bone density have not been indicated, there is concern for the adequacy of the caloric intake of pure vegetarians. Pure vegetarians have been found to have problems meeting caloric needs (81,82) and to have a lower weight than lacto-ovo-vegetarians or omnivores (83,84) indicating a lower, though not necessarily inadequate, caloric intake.

Osteoporosis, a major health problem among the elderly, is a condition whose etiology may be related to many things,
including diet. The loss of bone mass appears to be an age-related phenomenon occurring with greater or lesser frequency among most populations. The ingestion of high levels of protein has been shown to induce hypercalciuria and a negative calcium balance which may have a secondary effect on bone mass. Populations consuming high animal protein diets, such as Eskimos, have been found to have an accelerated rate of bone loss. Groups consuming fewer animal proteins, such as lacto-ovo-vegetarians, may have a slower rate of bone loss. Perhaps indirectly related to bone density through its relationship to body weight is caloric intake. Lacto-ovo-vegetarians tend to consume fewer calories than omnivores.
CHAPTER 3

EXPERIMENTAL PROCEDURE

Selection and Classification of Subjects

Seventy-nine women, 43 vegetarians and 36 nonvegetarians, aged 40 years and over were surveyed as to dietary intakes and the physical measurements of height, weight, and bone density. The project was approved by the Human Rights Committee of the University of Tennessee. Data were collected from March to June, 1976. Subjects were located using membership lists supplied by area churches and clubs. Women were contacted by telephone and by visits to their homes and/or central meeting places. Participants were informed of the purpose and details of the study and were asked to sign consent forms (Appendix) if they were interested in participating in the study.

The women were classified as vegetarians or nonvegetarians on the basis of meat consumption during the time they kept their 7-day dietary record. All 43 vegetarian subjects of this sample consumed no meat during that time. The 36 nonvegetarian subjects of the study consumed 7 or more servings of meat during the 7-day period.

Collection of Dietary Information

Dietary information was obtained from 7-day dietary records and dietary histories (Appendix). Verbal and written
instructions (Appendix) were given for measuring and recording the dietary intakes. Subjects were supplied with a set of measuring cups, measuring spoons, and a plastic ruler to help estimate portions. Amounts and kinds of dietary supplements were also recorded. The 7-day records were returned by mail or in person to the research team.

Food items recorded on the dietary sheets were summarized, coded, and the amounts converted to grams. The code numbers used were those listed in USDA Handbook No. 8 (85) with additional numbers established by project workers. Conversion of the food measures as cups, cubic inches, etc., to grams was accomplished using values given in Nutritive Values of American Foods in Common Measures (86), Food Values of Portions Commonly Used, by Church and Church (87), as well as data supplied by Loma Linda Foods, Worthington Foods, and other food manufacturers. The most commonly used items not found in Handbook No. 8 (85) were coded and nutrient compositions supplied by the manufacturers were added to the computer tape. Code numbers and amounts of the foods were placed on data cards, total and average daily nutrient intakes were calculated by computer using values given in Handbook No. 8 (85) and those additional values added by project workers. Nutrients of food items not occurring on the tape were added manually. Nutrients obtained from vitamin and mineral supplements were also placed on the data cards used
for statistical analysis and added by computer to the nutrient intakes from food.

**Bone Density Measurements**

Two instruments were used to measure bone density values for each subject. A bone densitometer developed by the Department of Nutrition, University of Tennessee, Knoxville, was used to estimate bone mineral content of the left phalanx 5-2 of each subject (88,89). The bone densitometer scans a central pathway of the phalanx 5-2 with a low-intensity x-ray beam. The elliptical shape of the bone is taken into consideration by making anteroposterior and lateral scans. An absorption curve of a reference wedge with similar x-radiation absorption characteristics to those of hydroxyapatite was made after each lateral tracing. The bone density index was calculated using these scans and expressed as x-ray gram equivalents of alloy/cc of bone.

The left distal radius of each woman was scanned using a Norland-Cameron bone mineral analyzer (90). This instrument uses the principle of photon absorptiometry to determine bone mineral content. An $^{125}$I source and detector unit simultaneously pass below and above, respectively, a scan site on the radius or ulna. The quantity of energy absorbed is proportional to amount of bone mineral. Bone width is also computed by the instrument. Bone mineral in terms of g/cm and bone width in cm are displayed digitally by the instrument.
The bone mineral content is expressed as \( \text{g/cm}^2 \) and is calculated by dividing the bone mineral (\( \text{g/cm} \)) by the bone width (cm).

**Anthropometric Measurements**

Both height and weight were determined at the time of bone density scanning. Height was measured to the nearest 1/4 inch and weight to the nearest pound with the subjects wearing indoor clothing but no shoes.

**Statistical Analysis**

The Statistical Analysis System (a computer software package) developed by Barr and Goodnight (91) was used to calculate means and standard errors and to perform regression analysis. The Student's t-test was used to determine whether means between the vegetarians and nonvegetarians differed significantly.

Simple linear and stepwise multiple regression analyses were used to examine relationships between a variable and other variables that might affect it. The computer program for multiple regression analysis sequentially relates each independent variable to the defined dependent variable. That is, the level of significance as shown by the F value of each successive independent variable shows its incremental contribution toward explaining the variation in the dependent variable. The slopes of the regression lines of the
vegetarian and nonvegetarian groups were tested for significant differences using an F-test for equality of slopes (92).
CHAPTER 4

RESULTS

Descriptive data on the 2 experimental groups are shown in Table 1. The 43 vegetarian subjects had a mean age of 57.1 years and had been vegetarians for an average of 33.6 years. One of these subjects was a vegan, the remainder were lacto-ovo-vegetarians. The 36 nonvegetarian subjects had a mean age of 58.8 years. Mean height (63.46 inches) and weight (137.7 pounds) of the vegetarians did not differ significantly from those measurements of the nonvegetarians (63.49 inches and 141.6 pounds). The mean bone density index of the phalanx 5-2 of the vegetarian group was 1.12 gram equivalents/cc of bone which did not differ significantly from that of the nonvegetarians, i.e., 1.18 gram equivalents/cc. The mean value for the bone mineral content of the radius of the vegetarians was 0.68 g/cm$^2$, not significantly different from that (0.67 g/cm$^2$) of the nonvegetarians.

The mean energy intake of the vegetarian group was 1600 kcal with 16.2% of the calories coming from protein. The nonvegetarian group had a mean energy intake of 1578 kcal with 17.0% of the calories coming from protein. The vegetarians consumed 64.6 g protein per day and the nonvegetarians averaged 66.6 g protein per day. None of the above differences in nutrient intakes between vegetarians and
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<th>Parameter</th>
<th>Experimental Group</th>
<th>Significance of Difference</th>
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<tr>
<td></td>
<td>Vegetarian (n=43)</td>
<td>Nonvegetarian (n=36)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>57.1 ±1.9</td>
<td>58.8±2.0</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>63.46±0.40</td>
<td>63.49±0.40</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>137.7±4.2</td>
<td>141.6±3.9</td>
</tr>
<tr>
<td>Bone density index, phalanx 5-2 (g/cc)</td>
<td>1.12±0.04</td>
<td>1.18±0.04</td>
</tr>
<tr>
<td>Bone mineral content, radius (g/cm²)</td>
<td>0.68±0.02</td>
<td>0.67±0.02</td>
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<tr>
<td>Energy (kcal/day)</td>
<td>1600±65</td>
<td>1578±52</td>
</tr>
<tr>
<td>Protein (g/day)</td>
<td>64.6±3.0</td>
<td>66.6±2.5</td>
</tr>
<tr>
<td>Fat (g/day)</td>
<td>57.2±3.1</td>
<td>62.6±2.8</td>
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<td>Calories from protein (%)</td>
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<td>17.0±0.5</td>
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<tr>
<td>Calories from fat (%)</td>
<td>31.7±0.4</td>
<td>35.5±0.8</td>
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¹Significance tested by t-test.
²Values shown are mean ± SE.
³P < 0.05.
nonvegetarians were significant. The nonvegetarian group consumed 35.5% of their calories as fat, significantly more (P < 0.01) than that of the vegetarian group, 31.7%.

The mean age of all subjects was 57.9 years; computing mean values of the variables adjusting to this age (Table 2) showed percent of calories from fat to be the only variable that differed significantly (P < 0.01). Among the physical measurements, the largest difference was in weight with the vegetarian group averaging 137.3 pounds and the nonvegetarian group averaging 142.1 pounds. Energy intake adjusted to 57.9 years was 1591 kcal among the vegetarians and 1585 kcal among the nonvegetarians. In the nonvegetarian group protein intake was 66.9 g or 17.0% of total calories; in the vegetarian group corresponding values were 64.3 g or 16.2%. Percent of the calories coming from fat was significantly higher (P < 0.01) among the nonvegetarians (35.6%) than among the vegetarians (31.5%).

The mean values of the vegetarian and nonvegetarian subjects grouped by age in decades are shown in Table 3. There was a tendency for all physical measurements and dietary intake values to decrease with age. The nonvegetarians tended to have higher physical measurement values at all age intervals than that of the vegetarians except for height in the 60-69 year group and mean bone mineral content at age 50-59 years. The nonvegetarians tended to have higher mean
TABLE 2
VALUES OF PHYSICAL AND DIETARY FACTORS ADJUSTED FOR THE MEAN AGE OF THE SUBJECTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corrected Mean Value of Variable(^1)</th>
<th>Significance of Difference(^2)</th>
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<tr>
<td></td>
<td>Vegetarian (n=43)</td>
<td>Nonvegetarian (n=36)</td>
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<tr>
<td>Height (inches)</td>
<td>63.4</td>
<td>63.6</td>
</tr>
<tr>
<td>Weight (pounds)</td>
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<td>142.1</td>
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<tr>
<td>Bone density index, phalanx 5-2 (g/cc)</td>
<td>1.11</td>
<td>1.19</td>
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<tr>
<td>Bone mineral content, radius (g/cm(^2))</td>
<td>0.68</td>
<td>0.67</td>
</tr>
<tr>
<td>Energy (kcal/day)</td>
<td>1591</td>
<td>1585</td>
</tr>
<tr>
<td>Protein (g/day)</td>
<td>64.3</td>
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<tr>
<td>Fat (g/day)</td>
<td>56.6</td>
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<tr>
<td>Calories from protein (%)</td>
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<td>17.0</td>
</tr>
<tr>
<td>Calories from fat (%)</td>
<td>31.5</td>
<td>35.6</td>
</tr>
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\(^1\)Values corrected to mean age (57.9 years) of both groups.

\(^2\)Significance indicated by F value.

\(^3\)P < 0.05.
TABLE 3
MEAN VALUES OF PHYSICAL AND DIETARY FACTORS OF VEGETARIAN AND NONVEGETARIAN SUBJECTS GROUPED BY AGE

<table>
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<th>Parameter</th>
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<td>NV (n=11)</td>
<td>NV (n=8)</td>
<td>NV (n=8)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>44.8</td>
<td>43.0</td>
<td>53.2</td>
<td>64.3</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>64.0</td>
<td>65.1</td>
<td>64.2</td>
<td>62.5</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>139.0</td>
<td>149.1</td>
<td>143.9</td>
<td>132.6</td>
</tr>
<tr>
<td>Bone density index, phalanx 5-2 (g/cc)</td>
<td>1.26</td>
<td>1.31</td>
<td>1.21</td>
<td>1.00</td>
</tr>
<tr>
<td>Bone mineral content, radius (g/cm²)</td>
<td>0.75</td>
<td>0.77</td>
<td>0.72</td>
<td>0.60</td>
</tr>
<tr>
<td>Energy (kcal/day)</td>
<td>1886</td>
<td>1653</td>
<td>1536</td>
<td>1482</td>
</tr>
<tr>
<td>Protein (g/day)</td>
<td>73.1</td>
<td>70.4</td>
<td>63.3</td>
<td>64.0</td>
</tr>
<tr>
<td>Fat (g/day)</td>
<td>72.2</td>
<td>65.3</td>
<td>53.4</td>
<td>49.0</td>
</tr>
</tbody>
</table>

1Vegetarian.
2Nonvegetarian.
intakes of energy, protein, and fat at all age intervals except that of 40-49 years than did the vegetarians.

Using regression analysis, decrements per decade in the physical measurements and dietary intakes were calculated (Table 4). Height decreased significantly (P < 0.01) in both groups, but more rapidly in the nonvegetarians (1.048 inches per decade) than in the vegetarians (0.867 inches per decade). Weight did not decrease significantly with age but the loss tended to be greater among the nonvegetarians who showed a decrease of 5.185 pounds per decade than among the vegetarians who showed a 4.945 pound per decade decrease.

Both bone density measurements showed significant (P < 0.01) decreases with age. In the vegetarians the bone density index of the phalanx 5-2 decreased 0.12 gram equivalents/cc and bone mineral content of the radius decreased 0.060 g/cm² per decade compared to the decrease in the bone density index of 0.11 gram equivalents/cc and the bone mineral content decrease of 0.070 g/cm² of the nonvegetarians per decade.

Energy intake in the vegetarians decreased significantly (P < 0.05) with age (115 kcal per decade); that of the nonvegetarians decreased 75 kcal per decade. Protein intake and percent of the calories coming from protein tended to decrease with age in both groups but not significantly. The vegetarians had a nonsignificant decrease in protein intake
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Vegetarian (n=43)</th>
<th>Nonvegetarian (n=36)</th>
<th>Significance of Difference Vegetarians vs Nonvegetarians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (inches)</td>
<td>-0.867**</td>
<td>-1.048**</td>
<td>NS</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>-4.94</td>
<td>-5.18</td>
<td>NS</td>
</tr>
<tr>
<td>Bone density index, phalanx 5-2 (g/cc)</td>
<td>-0.12**</td>
<td>-0.11**</td>
<td>NS</td>
</tr>
<tr>
<td>Bone mineral content, radius (g/cm²)</td>
<td>-0.06**</td>
<td>-0.07**</td>
<td>NS</td>
</tr>
<tr>
<td>Energy (kcal/day)</td>
<td>-115*</td>
<td>-75</td>
<td>NS</td>
</tr>
<tr>
<td>Protein (g/day)</td>
<td>-4.5</td>
<td>-3.4</td>
<td>NS</td>
</tr>
<tr>
<td>Fat (g/day)</td>
<td>-7.4*</td>
<td>-5.4*</td>
<td>NS</td>
</tr>
<tr>
<td>Calories from protein (%)</td>
<td>-0.04</td>
<td>-0.13</td>
<td>NS</td>
</tr>
<tr>
<td>Calories from fat (%)</td>
<td>-1.8**</td>
<td>-1.4*</td>
<td>NS</td>
</tr>
</tbody>
</table>

1Significance tested by F test for equality of regression slopes.

2Regression slope significantly different from zero by F test, *P < 0.05, **P < 0.01.

3P < 0.05.
of 4.5 g or 0.04% of the calories coming from protein while the nonvegetarians showed a decrease of 3.4 g or 0.13% of total calories per decade. Fat intake decreased significantly (P < 0.05) per decade among both groups—7.4 g among the vegetarians and 5.4 g among the nonvegetarians. Percent of calories from fat decreased significantly (P < 0.01) among the vegetarians (1.8% per decade). The nonvegetarians also showed a significant (P < 0.05) decrease in calories coming from fat of 1.4% per decade. The regressions of the 2 groups did not differ significantly from each other for any of the parameters studied.

Simple linear regression analysis showed age to be highly (P < 0.01) negatively related to the bone mineral content of the radius among both groups. Among the vegetarians, bone mineral content of the radius was positively related (P < 0.05) to weight, height, protein intake, total caloric intake, fat intake, and percent of calories coming from fat. Among the nonvegetarians, there was a positive relationship (P < 0.05) between that bone density measurement and weight, height, and protein intake.

Stepwise multiple regression analysis showed the bone mineral content of the radius and the bone density index of the phalanx 5-2 among the vegetarians to be significantly negatively related (P < 0.01) to age. Among the vegetarians, there was no relationship between bone density and any of the
other parameters studied. Among the nonvegetarians, the analysis showed bone density of the radius to be significantly related negatively to age; positively to protein intake when age, weight, height, and caloric intake were held constant; negatively to caloric intake when age, protein intake, weight, and height were held constant; and positively to weight when age, protein intake, caloric intake, and height were held constant ($P < 0.05$). Among the nonvegetarians the bone density index of the phalanx 5-2 was significantly related ($P < 0.05$) negatively to age, but not to any of the other parameters studied.

The nonvegetarians exhibited significantly ($P < 0.05$) greater variation around the regression line when the bone mineral content of the radius was regressed on age; on fat intake; and on age when protein and energy intakes were considered. Significantly greater variation was found in the vegetarians than in the nonvegetarians when caloric intake was regressed on age.

Tests between the 2 groups for equality of the regression slopes showed that, generally, the slopes did not differ. There were significant ($P < 0.05$) differences in the slopes for the bone mineral content of the radius regressed on age and caloric and protein intakes holding any 2 of the variables constant. The slope of this line was greater in the nonvegetarian group. There was also a significant ($P < 0.01$)
heterogeneity of slopes when the bone mineral content of the radius was regressed on age holding weight, height, and protein and caloric intakes constant. The slope of this line was greater in the vegetarian group than in the nonvegetarian group.
CHAPTER 5

DISCUSSION

The similarities existing between the vegetarian and nonvegetarian groups were a striking feature of this study. This is evidenced by the similarity of the mean values for the physical measurements and nutrient intakes.

The mean values of the bone density indices of the phalanx 5-2 of both groups were slightly higher than that found by Odland et al. (93). The bone mineral content of the radius in both groups was higher than that reported for similar age groups by Goldsmith et al. (90) but comparable to that obtained by Justice et al. (75) in their study of institutionalized elderly females.

The loss of bone mineral accompanying aging found in this study is consistent with the findings of others (2,25-29,31,90,93,94). Garn (9) stated that most research indicates the adult bone loss of white females to be about 25%; this is the same amount of loss observed for the bone mineral content of the radius in this study. Using the bone density of the phalanx 5-2, a decrease of 35% in the vegetarian group and 26% in the nonvegetarian group was noted when comparing subjects of ages 40-49 years with those of over 70 years of age.
The mean heights of both vegetarian and nonvegetarian groups compared favorably to that given in the RDA for this age group (65 inches) although both mean weight values were higher than the RDA value of 128 pounds (38). Decrements in height with age are comparable to those reported elsewhere (3). The loss of height with aging may be related to the loss of bone mineral (73,77,80); that is, bone demineralization frequently results in a collapse of the vertebrae and a subsequent reduction in height (9). In both groups height was significantly negatively correlated to bone mineral content of the radius. Multiple regression techniques did not show this relationship indicating that other factors are more significantly related to bone density than is height.

In agreement with Smith et al. (73) the decrease in weight with increasing age was nonsignificant. The decrease did not differ significantly between the vegetarian and nonvegetarian groups. Using simple regression, weight was significantly related to the bone mineral content of the radius of both groups. Multiple regression analysis showed body weight to be positively related to bone mineral content when age, protein intake, caloric intake, and height were held constant in the nonvegetarians. A relationship between body weight and bone density has been found by other workers (73,77,78).

Age-related decrements in consumption of calories, protein, and fat observed in this study were in agreement
with those reported by others (73,75,77,94,96). The mean caloric intakes of both groups were below the 1800 kcal RDA for women over age 51 (38); it decreased significantly with age among the vegetarians. Caloric intake of the nonvegetarians was negatively related to bone mineral content when age, protein, weight, and height were held constant.

Protein intakes of both groups were above the 45 g RDA (38); Hardinge et al. (40) reported higher levels of intake for young adult vegetarians and nonvegetarians. Protein intake decreased with age; somewhat more among the vegetarians than among the nonvegetarians. However, percent of calories from protein decreased only slightly; this is in agreement with Exton-Smith (96).

Total fat intake and percent of calories from fat was significantly higher in the nonvegetarians compared to the vegetarians; this may be due, in part, to the difference in fat levels of most plant and animal protein sources (97). Most of the fat normally present in soybeans is removed during the extraction of the protein (98). The wide use of textured vegetable protein products was noted among the vegetarians which may help to explain the lower fat intake of this group.

Nutrient intake values are lower than those reported by Peterson (94) and Odland et al. (95). Justice et al. (75) and Thompson (99) reported intakes of energy, protein, and fat of older women that compare favorably with the mean
intakes of those with those reported by others (73,75,77,94-96). The mean caloric intakes of both groups were below the 1800 kcal RDA for women over age 51 (38); it decreased significantly with age among the vegetarians. Caloric intake of the nonvegetarians was negatively related to bone mineral content when age, protein, weight, and height were held constant.

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Nutrient intake values are lower than those reported elsewhere (94.95). Justice et al. (75) and Thompson (99) reported intakes of energy, protein, and fat of older women
that compare favorably with the mean intakes of those nutrients found in this study. It is interesting to note that the only vegan in the group, who was 86 years of age, had a higher daily protein and lower daily energy and fat intakes than the mean values for her age group.

The significant relationship between protein intake and bone density among the nonvegetarians is not in agreement with the findings of Ellis et al. (31) or of Mazess et al. (25-28). Neither of the groups had mean protein intakes as high as those in studies reporting bone demineralization associated with the level of dietary protein (25-29). As in other studies, these results lead to the conclusion that the etiology of osteoporosis is a composite of many factors.
SUMMARY

The purposes of this study were to compare differences in the physical measurements of height, weight, and bone density among female vegetarians and nonvegetarians and to determine relationships between these measurements and dietary intakes of energy and protein.

The 2 groups of women were similar with respect to their mean ages and physical measurements. Mean age of the vegetarians was 57.1 years while that of the nonvegetarians was 58.8 years. Mean physical measurement values of the vegetarians included height, 63.46 inches; weight, 137.7 pounds; bone density index of the phalanx 5-2, 1.12 g/cc; and bone mineral content of the radius, 0.68 g/cm$^2$. Corresponding values for these measurements for nonvegetarians were 63.49 inches, 141.6 pounds, 1.18 g/cc, and 0.67 g/cm$^2$, respectively.

Mean energy and protein intakes for the vegetarians, 1600 kcal and 64.6 g (16.2% of total calories) did not differ significantly from the 1578 kcal and 66.6 g (17.0% of total calories) mean intakes of the nonvegetarians. Mean fat intakes of the 2 groups were significantly different. The vegetarians averaged 57.2 g or 31.7% of total calories and the nonvegetarians averaged 62.6 g or 35.5% of total calories. Adjusting these mean values to the mean age of both groups,
showed only the percent of calories coming from fat to be significantly different (P < 0.01).

Calculating mean values for subjects in 10-year age intervals showed a tendency for all parameters studied to decrease with age. Using the regression equations to calculate per decade decrease showed height, weight, and bone density measurements decreased significantly (P < 0.01) with age. Among the dietary factors, only fat intake and percent of the calories as fat decreased significantly.

The slopes of the regression lines between the 2 groups differed significantly (P < 0.05) when bone mineral content of the radius was regressed on age, caloric intake, and protein intake holding any 2 of the variables constant. There was also a significant difference in the slopes when bone mineral content of the radius was regressed on age holding weight, height, protein intake, and caloric intake constant.

Age was the factor most significantly related to bone mineral content of the radius of both groups; this was a negative relationship. Both groups also showed positive relationships between bone mineral content of the radius and weight, height, and protein intake. Among the vegetarians there was a positive relationship between bone mineral content of the radius and caloric intake, fat intake, and percent of calories coming from fat. Using multiple regression analysis, age was again significantly related, negatively, to bone
mineral content in both groups. Among the nonvegetarians positive relationships were obtained between bone mineral content and protein intake holding age, weight, height, and caloric intake constant; and between bone mineral content and weight when age, protein intake, caloric intake, and height were held constant. Thus, the most important factor related to bone mineral status of these subjects, either vegetarian or nonvegetarian, was age.
REFERENCES


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 professional staff as not likely to be harmful to the participants involved or an inappropriate or unnecessary 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
<table>
<thead>
<tr>
<th>FOOD</th>
<th>KIND &amp; STATE</th>
<th>AMOUNT</th>
</tr>
</thead>
</table>

**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______**  **NONVEGETARIAN______**  **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 (includes 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 ___
Number of servings per day

4. Meat and Meat Alternates

Meat: beef ___ veal ___ lamb ___ pork ___ liver ___
fish ___ poultry ___ luncheon meats ___ other ___
Number of 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

1/76
We would like a record of what you eat for 7 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 the 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, cornflakes, 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.
Meats - 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:

<table>
<thead>
<tr>
<th>Raw Salad</th>
<th>Cheese Sandwich</th>
</tr>
</thead>
<tbody>
<tr>
<td>lettuce</td>
<td>bread</td>
</tr>
<tr>
<td>tomato</td>
<td>cheddar cheese</td>
</tr>
<tr>
<td>cucumber</td>
<td>lettuce</td>
</tr>
<tr>
<td>french dressing</td>
<td>mayonnaise</td>
</tr>
</tbody>
</table>

| 1 leaf            | 2 slices           |
| 1 slice           | 1 slice            |
| 2 slices          | 1 leaf             |
| 1 tablespoon     | 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 - Cambell'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 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" or 10" 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:

<table>
<thead>
<tr>
<th>FOOD</th>
<th>KIND AND STATE</th>
<th>AMOUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>cereal</td>
<td>oatmeal</td>
<td>3/4 cup</td>
</tr>
<tr>
<td>sugar</td>
<td></td>
<td>2 teaspoons</td>
</tr>
<tr>
<td>cream</td>
<td>half and half</td>
<td>1/4 cup</td>
</tr>
<tr>
<td>pancake</td>
<td>Hungry Jack Pancake</td>
<td>1, 6&quot; diam. 1/4&quot; thick</td>
</tr>
<tr>
<td>egg</td>
<td>fried</td>
<td>1 large</td>
</tr>
<tr>
<td>meat</td>
<td>baked ham</td>
<td>4&quot; x 2&quot; x 1&quot;</td>
</tr>
<tr>
<td>potatoes</td>
<td>mashed</td>
<td>3/4 cup</td>
</tr>
<tr>
<td>peas</td>
<td>canned</td>
<td>1/2 cup</td>
</tr>
<tr>
<td>butter on peas</td>
<td></td>
<td>1/2 teaspoon</td>
</tr>
<tr>
<td>milk</td>
<td>whole</td>
<td>1 cup</td>
</tr>
<tr>
<td>cake</td>
<td>choc., iced</td>
<td>2&quot; x 2&quot; x 1&quot;</td>
</tr>
</tbody>
</table>

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

Mary Elizabeth Kunkel was born on September 8, 1953, in Newport, Arkansas, where she received her elementary and secondary education. She attended the University of Central Arkansas, receiving a Bachelor of Science in Education with a major in home economics in May, 1975. The fall of that year she began graduate work at the University of Tennessee, Knoxville. In August, 1976, she received the Master of Science degree with a major in Nutrition.