Risk Factors for Osteoporosis Among Middle-Aged Women

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Objective: To investigate the risk factors for osteoporosis among a sample of middle-aged women. Methods: Adipose tissue and bone mineral density levels at the left femur, lumbar spine, and total body were assessed using dual-energy x-ray absorptiometry (DXA). Subjects (n=342) were surveyed regarding a variety of osteoporosis-related risk factors. Forward stepwise multiple regression procedures were utilized. Results: Menstrual status, hormone replacement therapy, adipose tissue, and dairy product intake were retained in the regression models. Conclusions: Osteoporosis prevention programs need to emphasize the importance of hormonal status and body composition in addition to obtaining adequate calcium intake.

Key words: bone mineral density, risk factors, dual-energy x-ray absorptiometry, osteoporosis.

Osteoporosis is a crippling condition that results in premature mortality and significant morbidity that may be manifested in the form of fractures, bone deformity, and chronic pain. Osteoporosis is one of the most prevalent diseases of aging, affecting 25-30 million people in the United States, 80% of whom are women. It is responsible for approximately 250,000 hip fractures a year and an annual total of 1.5 million fractures in the United States. More than half of all women will experience an osteoporotic fracture sometime during their lifetimes.

The economic cost of osteoporosis is estimated to be $13.8 billion annually, of which $10.3 billion is for treatment of Caucasian women. These expenditures are for fractures alone and do not include indirect costs of lost wages or productivity for the affected people or their caretakers. The impact of osteoporosis on healthcare costs, quality of life, and total morbidity and mortality demonstrates an urgent need to discover factors that contribute to osteoporosis and to find ways to prevent it. The staggering economic and social burden caused by hip fractures alone dictates an immediate need for research to define optimal primary prevention strategies.

Osteoporosis has been studied most extensively in older women. Risk factors for osteoporosis among older women include advancing age, family history, estrogen depletion, racial inheritance (being Caucasian), physical inactivity, low body weight, smoking, abusing alcohol and/or other drugs, and low calcium in-
Although postmenopausal women have the highest incidences of osteoporosis, declines in bone density that result in osteoporosis begin in earlier years. Achievement of high levels of peak bone mineral density around age 30 and minimizing bone density losses in later years are recommendations for preventing osteoporosis. Osteoporosis research is needed among women of younger ages. Currently the knowledge base regarding risk factors among middle-aged women is limited. The purpose of this cross-sectional study was to examine the risk factors for osteoporosis among a sample of middle-aged women.

MATERIALS AND METHODS

Recruitment of Subjects

Following approval by the institutional review board of the University of Arkansas at Fayetteville, recruitment efforts commenced that used a variety of avenues to encourage participation. A flyer was developed that included a list of dangers of osteoporosis, a photo of a disfigured woman with osteoporosis, and contact information regarding the study. Recruitment efforts extended across a 4-county region to encourage participant involvement from the northwest region of the state. Targeted settings included the local university, the school systems, libraries, community centers, hair and beauty salons, shopping centers, and grocery stores. Flyers were also distributed to health department offices, hospitals, clinics, and doctors' offices. Media outlets including newspapers, television, and radio networks were utilized.

Efforts were made to recruit women of all races and to parallel the ethnic demographics of the region. Health departments and clinics that provide medical care to underserved populations were included when distributing recruiting materials. In addition, the primary researcher contacted health care providers who worked with underserved populations to explain the study and encourage recruitment of members to represent the community, specifically racial minorities. Unfortunately these efforts did not recruit substantial numbers of minority women to perfectly reflect the demographics of the region (86.2% are Caucasian, 8.4% are Hispanic, 1.2% are African American, 1.2% are Asian, 1.4% are Native American, and 1.6% are from other race or a combination of races). Of the 342 who completed the study, 319 (93%) were Caucasian, 7 (2%) women were Asian, 7 (2%) were Hispanic, 4 (1%) were Native American, 4 (1%) were African American, and 1 (.3%) was from India. The study closely parallels the ethnicity of the region with the exception of inadequate numbers of Hispanic women.

The mean age was 49 years with ages ranging from 30 to 64 years. The average years of education were 16 years (with a range from 9 to 28 years). The average height was 64 inches (with a range of 56 to 74 inches). The average weight was 154 pounds (with a range of 74 to 302 pounds).

Procedure

After providing written informed consent, women completed bone density measurements, body composition assessments (height, weight, body fat), and a questionnaire. Body height and weight were measured using a Detecto scale (Detecto Scales, Incorporated, Brooklyn, New York), with subjects wearing no shoes and light clothing. The outcome variables, bone mineral density (BMD) at the spine (L2-L4), left femur, and total body were assessed by dual-energy x-ray absorptiometry (DXA Lunar, Prodigy, software version 2.05). Body weight and total body fatness are significant and consistent predictors of bone density. People with low body weights are considered at risk for developing osteoporosis. Previous research indicates that higher body fat mass may have protective effects on bone health possibly due to higher blood levels of estrogen among women with more body fat or due to the mechanical loading of excess weight on bones. Adipose tissue was assessed using DXA, the gold standard for measuring body fat as well as bone mineral density.

The in vivo precision of DXA has been found to be approximately 1% for the lumbar spine and 1%-2% for the proximal femur. Subjects lay supine on the scanner table and were wearing no metal when the scan was performed. A single certified densitometry technologist conducted all DXA measurements. After bone mineral density levels were obtained, the primary researcher provided each participant with an individual consultation regarding her bone density results.
**Instrumentation**

Subjects completed consent forms and the *Osteoporosis Preventing Behaviors Survey* (developed by Sedlak and Dohney)\(^23\) to obtain information regarding osteoporosis-related risk factors. Data from the *Osteoporosis Preventing Behaviors Survey* were used to examine 9 independent variables that were frequently cited risk factors for osteoporosis among older women.\(^6,24\)

They included family history of osteoporosis, family history of osteoporotic fracture, number of menses in the past 12 months, utilization of hormone replacement therapy, physical activity, dairy product intake, smoking status, and use of calcium supplements. Demographic information was obtained by querying women regarding their age in years, race, and years of education.

Research indicates that heredity appears to play an influential role in bone growth and mineral metabolism.\(^55\) Studies of twins and parent-offspring pairs have shown significantly higher correlations between bone density in monozygotic twins than in dizygotic twins.\(^6,26,27\)

Estimates of the proportion of adult variance in bone density determined by heredity range from 20 to 80%.\(^26,28\) The proportion of peak bone mass that is genetically determined ranges from 60 to 80%.\(^29,30\)

The influence of heredity was determined by self-reported information obtained from 2 questionnaire items: "Has your mother, aunt, sister, or maternal grandmother ever been told they have osteoporosis?" and "Has your mother, aunt, sister or maternal grandmother suffered from hip fractures?"\(^26\)

Research indicates that smokers experience more fractures from slight injury than do nonsmokers. A study of twins reports that women who smoked a pack of cigarettes a day throughout adulthood lost an extra 5 to 10% of their bone density by menopause.\(^31\) Smoking information was obtained from responses to the following item: "Do you currently smoke?"

Physical activity has been shown to have positive impacts on bone mineral density.\(^32-35\) The adaptations in aging skeletal muscle to exercise training enhance the ease of carrying out the activities of daily living and exert a protective effect on bone status.\(^36\) Recker and colleagues state that even modest physical activity is recommended to help minimize bone loss.\(^14\) Physical activity information was obtained from responses to the following items: "How many times a week do you participate in weight-bearing exercise such as walking, running or jogging, aerobics, dancing, or yard work?" and "How many minutes do you participate in bearing exercise?" Women who stated they participated in physical activity 20 minutes or more 3 or more days a week were considered physically active.\(^37,38\)

Calcium has long been recognized as important to bone health: Barger-Lux and Heaney discuss 12 intervention studies that established skeletal benefits of increased calcium intakes among menopausal women.\(^39\) The National Institutes of Health Consensus Development Conference on Optimal Calcium Intake concluded that adequate calcium intake is critical to achieving optimal peak bone mass and reducing bone loss associated with aging.\(^40\)

Optimal calcium intake is estimated to be 1,000 mg/day for women between ages 25 and 50 years and postmenopausal women on estrogen replacement therapy and 1,500 mg/day for postmenopausal women not on estrogen replacement therapy.\(^40\) Dairy product intake and calcium supplement use were selected to obtain information regarding calcium intake. Food frequency information is useful as it helps pinpoint food groups, and therefore nutrients, that may be deficient in the diet. Dairy consumption may assist in determining whether calcium may be lacking in the diet. Subjects were asked 4 questions to determine how often on an average day they consumed milk, yogurt, cheese, and ice milk or ice cream. Responses to these questions were summarized to give a total number of dairy products consumed per day. Subjects were also queried regarding their use of calcium supplements with the follow item: "Do you take a calcium supplement?" Then they were asked to list the brand name and the amount of calcium taken per day.

Bone mineral density dwindles rapidly when estrogen diminishes and menstruation ceases: bone resorption exceeds formation.\(^41\) Bone metabolism changes during menopause so that bone mineral withdrawal is accelerated.\(^42,43\) Hormone replacement therapy is recognized as a preventive and treatment therapy for osteoporosis.\(^44-47\)

Subjects were asked How many menstrual periods have you had in the past 12 months? Circle the number...
### Table 1

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Beta Weights&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Uniqueness Indices&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
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<tr>
<td>No. Menses</td>
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</tr>
<tr>
<td>HRT Status</td>
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<tr>
<td>Adipose Tissue</td>
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<tr>
<td>Dairy Product Intake</td>
<td>0.02</td>
<td>0.00</td>
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Note.
* Significance at P<0.0001

<sup>a</sup> Beta weights are standardized multiple regression coefficients obtained when bone mineral density of left hip was regressed on all 4 predictors.

<sup>b</sup> Uniqueness indices indicate the percentage of variance of bone mineral density accounted for by a given determinant beyond the variance accounted for by the other 3 predictors.

<sup>c</sup> For t tests that tested the significance of the beta weights df=330.

<sup>d</sup> For F tests that tested the significance of the uniqueness indices df=1330.

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between 0 and 12. Women were also asked Do you take a hormonal (estrogen) replacement? Circle yes or no. If yes, list the name of the drug and the amount taken each day.

### Statistical Analyses

Statistical analyses were performed using SAS™ version 8.02. Demographic information, family history of osteoporosis, family history of osteoporotic fracture, number of menses in the past 12 months, utilization of hormone replacement therapy, physical activity, dairy product intake, percent of adipose tissue, smoking status, and use of calcium supplements served as the independent variables and bone measurements were classified as dependent variables. Alpha was set at 0.05 a priori.

Descriptive statistics (means, standard deviations, percentages) were calculated to describe the study population. A series of forward stepwise multiple regressions were performed at each skeletal site to predict the amount of variance in bone mineral measurements that could be explained by independent variables. Beta weights, standardized multiple regression coefficients, were obtained when bone mineral density values were regressed on predictors. Uniqueness indices were calculated to indicate the percentage of variance of bone mineral density accounted for by a given determinant beyond the variance accounted for by the other predictors.

### RESULTS

More than half of the sample (188 or 55%) reported that they engaged in weight-bearing exercise at least 3 to 4 times per week for 20 to 30 minutes whereas only 43 (or 13%) of women reported that they engage in non-weight-bearing exercise. The average number of dairy products consumed per day was 1.7 per day. Cheese was consumed more often than other dairy products. Seventy-three women (21%) reported that they never drink milk, 106 (31%) never consume yogurt, 24 (7%) do not eat cheese, and 88 (26%) reported that they do not consume any ice cream or ice milk. More than half of the sample (237 or 69%) reported taking a calcium supplement.

Regarding estrogen status, 72 (21%) women were estrogen deplete (meno-
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Table 2
Beta Weights and Uniqueness Indices Predicting Bone Mineral Density of the Spine (N=342)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Beta Weightsa</th>
<th>Uniqueness Indicesb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>t</td>
</tr>
<tr>
<td>No. Menses</td>
<td>0.41</td>
<td>7.68*</td>
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<tr>
<td>HRT Status</td>
<td>0.17</td>
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<tr>
<td>Adipose Tissue</td>
<td>0.31</td>
<td>6.28*</td>
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<tr>
<td>Dairy Product Intake</td>
<td>0.03</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Note.
* Significance at P<0.0001
a Beta weights are standardized multiple regression coefficients obtained when bone mineral density of spine was regressed on all 4 predictors.
b Uniqueness indices indicate the percentage of variance of bone mineral density accounted for by a given determinant beyond the variance accounted for by the other 3 predictors.
c For t tests that tested the significance of the beta weights df=330.
d For F tests that tested the significance of the uniqueness indices df=1330.

pausal or postmenopausal and not taking a hormone replacement). Two hundred seventy (79%) were either premenopausal or taking a hormone replacement. Only 22 women (6%) reported that they smoke cigarettes.

Using multiple regression, bone mineral density for the left femur, spine and total body were regressed on the linear combination of independent variables to generate 3 models (see Tables 1, 2 and 3). The equations containing menstrual status, hormone replacement therapy, adipose tissue, and dairy product intake accounted for 29.4% of the variance of the left femur BMD, F(4,330)=34.37, P<0.0001, adjusted R²=28.56%, 35.67% of the variance of the spine BMD, F(15,218)=5.01, P<0.0001, adjusted R²=20.56%, and 24.67% of the total body BMD, F(15,218)=4.76, P<0.0001, adjusted R²=19.49. Family history, physical activity, smoking, and calcium supplement use were not significant variables.

Beta weights and uniqueness indices were reviewed to assess the relative importance of the 4 variables in predicting bone mineral density. The uniqueness index for a given independent variable was the percentage of variance in the criterion accounted for by that variable, beyond the variance accounted for by the other variables. Beta weights and uniqueness indices are provided in Tables 1, 2 and 3.

All coefficients were in the predicted direction. The tables show that menstrual status, taking hormone replacement therapy, and adipose tissue displayed significant beta weights for all 3 bone density measures (P<0.0001). Menstrual status demonstrated the substantial beta weights for left femur (.38), spine (.41), and total body (.35). Adipose tissue also demonstrated substantial beta weights for left femur (.41), spine (.31), and total body (.31). Beta weights for hormone replacement therapy were .17 for the left femur and spine and .20 for the total body. Beta weights for dairy product intake were .02 for left femur, .03 for spine, and .06 for total body and were not significant. Although dairy product intake improved the overall model, it did not display a strong influence separate from the other variables in the model.

The results regarding uniqueness indices matched those for beta weights, in
Table 3

Beta Weights and Uniqueness Indices Predicting Bone Mineral Density of the Total Body (N=342)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Beta Weightsa</th>
<th>Uniqueness Indicesb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>t'</td>
</tr>
<tr>
<td>No. Menses</td>
<td>0.35</td>
<td>6.58*</td>
</tr>
<tr>
<td>HRT Status</td>
<td>0.20</td>
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<tr>
<td>Adipose Tissue</td>
<td>0.31</td>
<td>6.25*</td>
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<tr>
<td>Dairy Product Intake</td>
<td>0.06</td>
<td>1.16</td>
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</table>

Note.
* Significance at P<0.0001

a Beta weights are standardized multiple regression coefficients obtained when bone mineral density of total body was regressed on all 4 predictors.
b Uniqueness indices indicate the percentage of variance of bone mineral density accounted for by a given determinant beyond the variance accounted for by the other 3 predictors.
c For t tests that tested the significance of the beta weights df=330.
d For F tests that tested the significance of the uniqueness indices df=1330.

that menstrual status, hormone replacement therapy and adipose tissue displayed significant indices. Menstrual status accounted for 17% of the variance of the left hip, 9% of the variance of spine and 10% of the variance of the total body beyond the variance accounted for by the other variables. Hormone replacement therapy accounted for 17% of the variance of the left hip, 14% of the spine, and 3% of the total body. Adipose tissue accounted for 2% of the variance of the left femur and spine, and 9% of the total body.

DISCUSSION

The purpose of this investigation was to explore risk factors for osteoporosis among middle-aged women. The sample consisted of 342 well-educated, primarily Caucasian women aged 30 to 64 years (the mean age was 49 years). A limitation of this study is that the sample is not representative of all ethnicities. However, it appears to be closely representative of the 4-county area in northwest Arkansas with the exception of inadequate numbers of Hispanic women. Although extensive efforts were made to recruit women of all ethnicities, efforts were not completely successful. A volunteer bias is present, which is a limitation of the study. Although the study is not perfectly representative of the local area, it may be considered representative of the highest-risk ethnic group, Caucasian women. The majority of osteoporosis-related health care expenditures (over $10 billion per year) are for Caucasian women. National health objectives recommends targeting older Caucasian women because they are the group at highest risk for osteoporosis.

Research indicates that heredity appears to play an influential role in bone growth and mineral metabolism. Family history of osteoporosis and osteoporotic fracture was not significantly associated with bone mineral density. Results of the present study did not find genetics to be a significant predictor for osteoporosis among this sample of middle-aged women.

Research indicates that smokers experience more fractures from slight injury than do nonsmokers. In the current study, smoking was not a significant factor for bone mineral density. This finding could indicate that the deleterious effects of smoking on bone healthwould be more pronounced in women who are not at high risk for osteoporosis.
may not manifest themselves until later in life. The small percentage of smokers (6%) may have affected the analysis of smoking as a predictor. The small number of smokers is not representative of actual numbers of smokers in the region. This is a limitation related to volunteer bias (volunteers for health studies tend to practice healthier behaviors than those who do not volunteer).

Physical activity has been shown to have positive impacts on bone mineral density. More than half of the sample (55%) reported that they engaged in weight-bearing exercise according to recommendations—20 minutes, 3 times a week. The sample of the current study appears to be far more physically active than the general population: most Americans exercise on an infrequent basis or are completely sedentary. Many people are inactive; only 22% of Americans engage in regular physical activity. Contrary to current research, physical activity was not significant in the present study. A possible explanation for this finding may be that most women who did not meet the recommended criteria for physical activity were still somewhat active in their daily lives. Most women in this study reported that they were involved in caring for others, managing the affairs of their families and taking care of their homes.

Adequate calcium intake during childhood and adolescence is essential to attain optimal bone size and mass. Unfortunately, few girls meet the RDA for calcium during their bone-forming years. Many girls start their adult lives with less than optimal bone density. In the present study, the average number of dairy products consumed per day was 1.8 per day. Cheese was consumed more often than other dairy products. Seventy-three women reported that they never drink milk, 106 never consume yogurt, 24 do not eat cheese, and 88 reported that they do not consume any ice cream or ice milk. More than half of the sample (237) reported taking a calcium supplement. Only 41% consumed adequate amounts of calcium which is lower than the 46% of Americans who meet dietary recommendations regarding calcium intake. These results are consistent with other reports that women fall well below the recommended intakes for calcium.

This study examined frequency of dairy product intake as an indicator of calcium intake. Dairy product intake improved the variance in each regression model indicating the importance of adequate calcium. Beta weights and uniqueness indices for dairy product use were not significant indicating that although dairy product intake is contributory in the overall model; its influence above and beyond other variables was not significant.

Use of calcium supplements has been shown to improve bone density and has been recommended for people with lactose intolerance or others who do not consume adequate calcium. The current study examined use of calcium supplements and found that this variable was not significant. Traditionally, nutritionists have recommended obtaining calcium from foods rather than supplements, due to enhanced bioavailability and improved absorption of nutrients from foods. The current study supports this notion as dairy product intake was significant, but calcium supplement use was not.

Bone mineral density dwindles rapidly when estrogen diminishes and menstruation ceases: bone resorption exceeds formation. Bone metabolism changes during menopause so that bone mineral withdrawal is accelerated. Accelerated losses last for 10 years following menopause, then taper off, so that women again lose bone at the same rate as men their age. Hormone replacement therapy is recognized as a preventive and treatment therapy for osteoporosis. Other studies confirm these findings indicating exposure to hormone replacement therapy to be positively associated with bone mineral density.

The current study supports the importance of estrogen status on bone health. Women who had fewer menses and were not taking hormone replacement therapy had lower bone density levels than those of women who were estrogen replete. This study supports previous research regarding the protective effects of estrogen on bone density. Beta weights and uniqueness indices for HRT were significant, indicating that not only is HRT contributory in the overall model, but its influence above and beyond other variables also was significant.

During data collection when women were provided with the results from their bone density exams, several postmeno-
pausal women who were not on HRT were surprised to learn that their levels were low even though they seemed well-informed regarding the benefits of HRT for bone health. They stated that because they decided to avoid HRT, they choose to exercise and take calcium supplements, in hopes of avoiding bone loss. Results from the current study indicate that being physically active and consuming adequate calcium are not enough to forestall bone losses if women are estrogen deplete. Health promotion efforts should include education regarding the effects of estrogen depletion on bone health. Women are advised to consider hormone-replacement therapy as a preventive and treatment therapy for osteoporosis. Women should seek guidance from their physicians regarding the benefits versus risks of HRT. For example, women with existing cardiovascular disease may decide to avoid HRT. Women who decide to avoid HRT should monitor their bone density levels and talk with their physicians regarding other medications to preserve bone density. In addition, their calcium intakes should be increased. The National Institutes of Health recommend 1,500 mg/day of calcium for postmenopausal women who do not use estrogen replacement therapy.

Body weight and total body fatness are significant and consistent predictors of bone density. People with low body weights are considered at risk for developing osteoporosis. Previous research indicates that higher body weights and body fat mass may have protective effects on bone health, possibly due to higher blood levels of estrogen among women with more body fat or due to the mechanical loading of excess weight on bones. Results from the current study confirm the protective effect of adequate and excess adipose tissue. In the current study, women who had sufficient or excess body fat had significantly higher bone density levels than women with low body fat. Beta weights and uniqueness indices for percent body fat were significant indicating that body fat was contributory in the overall model, and its influence above and beyond other variables was also significant.

Health promotion efforts should emphasize the importance of achieving and maintaining healthy body weights. Women who are underweight should obtain assistance from a registered dietitian to develop a healthy plan for weight gain. A nutritious meal plan that meets current energy needs and provides an additional 500-700 calories per day can be designed to facilitate weight gain for underweight women. A balanced diet that includes adequate calories to promote weight gain will include 3 or more servings of dairy foods.

While the current study, along with other research, indicate that adequate and even excessive body fat is beneficial to bone density, health education efforts should encourage achievement of healthy body weights, not obesity. One study demonstrated that having excessive body weight offered no additional benefit when compared to being of normal body weight. Excessive body fat is associated with other chronic diseases as well. Health care professionals can encourage women to strive for healthy body weights to reduce risks of osteoporosis as well as risks of other chronic diseases.

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