

# Low Bone Mineral Density and Risk of Fracture in White Female Nursing Home Residents

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**T**HE INCIDENCE OF OSTEOPOROTIC fracture, especially at the hip, increases dramatically with age and is highest among white women.<sup>1</sup> Fractures in elderly, community-dwelling white women are associated with high health care costs, long recovery periods, and high mortality rates.<sup>2-4</sup> Low bone mineral density (BMD) is a strong predictor of fracture in postmenopausal, community-dwelling white women.<sup>5-7</sup> However, the relationship is less clear among white female nursing home residents, despite the high prevalence of osteoporosis and the nearly 10-fold higher hip fracture rate than in community-dwelling elderly persons.<sup>8</sup> Risk factors for fracture in other studies have included old age, impaired mobility, poor cognition, psychotropic medication use, and high risk of falls.<sup>8-13</sup> Recent evidence suggests that bone loss continues into the 9th and 10th decades and

For editorial comment see p 1018.

**Context** Low bone mineral density (BMD) is a strong risk factor for fracture in community-dwelling white women, but the relationship in white female nursing home residents, for whom fracture rates are highest, is less clear.

**Objective** To assess the relative contribution of low BMD to fracture risk in nursing home residents.

**Design** Prospective cohort study with baseline data collected April 1995 to June 1997, with 18 months of follow-up.

**Setting** Forty-seven randomly selected nursing homes in Maryland.

**Patients** A total of 1427 white female nursing home residents aged 65 years or older.

**Main Outcome Measure** Documented osteoporotic fracture occurring during follow-up as a function of baseline BMD measurements higher vs lower than the median, and after controlling for demographic, functional, cognitive, psychosocial, and medical factors.

**Results** A total of 223 osteoporotic fractures occurred among 180 women. Low BMD and transfer independence were significant independent risk factors for fracture in this nursing home sample ( $P < .001$ ) and the 2 factors acted synergistically ( $P = .06$ ) to further increase fracture risk. Compared with women whose BMD was higher than the median (0.296 g/cm<sup>2</sup>), those whose BMD was lower than the median had an unadjusted hazard ratio for risk of fracture of 2.1 (95% confidence interval [CI], 1.5-2.8); women who were independent in transfer had a hazard ratio of 1.6 (95% CI, 1.2-2.2) compared with women dependent in transfer. Among residents independent in transfer, those with BMD below the median had a more than 3-fold increase in fracture risk compared with those with higher BMD (unadjusted hazard ratio, 3.1; 95% CI, 2.2-4.4). Among residents dependent in transfer, those with BMD below the median had a 60% increase in fracture risk (unadjusted hazard ratio, 1.6; 95% CI, 1.1-2.3). Adjustment for covariates did not alter the BMD-fracture relationship.

**Conclusions** Our data indicate that low BMD and independence in transfer are significant predictors of osteoporotic fracture in white female nursing home residents.

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may accelerate,<sup>14-16</sup> which may combine with other factors to increase fracture risk in this population.

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We conducted a prospective cohort study of white women in a representative sample of nursing homes in Mary-

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land to determine whether low BMD predicts osteoporotic fractures independent of other risk factors. Knowing whether BMD contributes to fracture risk in this population may be useful for designing effective risk assessment and fracture prevention strategies in long-term care settings.

## METHODS

### Sample

Residents were recruited from facilities participating in the Maryland Long-Term Care Project, which is dedicated to the study of quality of life among long-term care residents. All 221 licensed long-term nursing facilities in Maryland were categorized by location and number of beds, and a stratified random sample of 47 homes was selected.<sup>17</sup> The cohort followed up longitudinally included white women aged 65 years or older. Residents were excluded if they were in a coma; had bone metastases, terminal cancer, a prosthetic implant in both wrists/forearms, significant open skin lesions on both hands/arms; or were admitted for rehabilitation only. Residents were randomly selected within a facility if eligible women exceeded a quota set to maintain representation across regional and bed strata. Institutional review board approval was obtained prior to study initiation. Written informed consent was obtained from residents or from family members if residents were unable to provide consent.

### Baseline Measures

Two trained teams of evaluators collected baseline data between April 1995 and June 1997. Distal radius BMD (bone mineral content/area) of the dominant arm was assessed with a DTX-100 single x-ray absorptiometer (Osteometer A/S, Rødovre, Denmark). Reliability of distal radius BMD was excellent.<sup>18</sup> The project radiologist (L.H.) reviewed the quality of all scans, discarding only 2% because of poor quality.

Demographic characteristics were collected from residents, family members, nursing home staff, and medical

records. The most recent Minimum Data Set (MDS), a valid and reliable comprehensive nurse-completed assessment of functional, cognitive, psychosocial, and medical status,<sup>19-22</sup> was obtained from each participant's chart. Variables derived from the MDS included functional status (dependency in transfer, dressing, eating, bathing, bed mobility, hygiene, and toileting), ambulatory status, vision, and history of falls in the past 180 days. Transfer and ambulatory independence appeared to capture similar information among those with both variables. Because 30% of the sample was missing information on ambulatory status, only transfer independence was used in analyses.

Cognition was assessed using the Mini-Mental State Examination (MMSE)<sup>23</sup> and depression using the Cornell Depression Scale.<sup>24</sup> Current medications, history of fracture, chronic disease information (for calculating a Charlson comorbidity score<sup>25</sup>), and height and weight were obtained from the resident's medical chart. Grip strength of the dominant side was measured using a Jamar hand dynamometer (Sammons Preston Inc, Bolingbrook, Ill).

### Follow-up

Trained medical record abstractors reviewed charts of all participants for new fractures during the 18 months following baseline examination. Fractures were counted only if documented by a radiographic report or written physician's note (suspected fractures were not included), and only osteoporotic fractures were included in these analyses. Osteoporotic fractures are those shown to be associated with low bone mass in elderly community-dwelling white women, and include vertebrae, hip, humerus, wrist, rib, clavicle, pelvis, leg, foot, and toes.<sup>26</sup> Excluded from analyses as non-osteoporotic were fractures of the face (n=6), fingers (n=8), ankle (n=9), and patella (n=4). Residents who died or were lost to follow-up were included in the analysis up to time of

death or loss to follow-up, after which they were censored in analyses.

### Analysis

Bone mineral density was standardized using the mean (SD) of the full cohort of white female nursing home residents. The BMD-to-fracture relationship was also assessed by comparing residents with values above and below the median BMD. The BMD-to-fracture risk relationship was illustrated graphically using quartiles.

Fracture rate for any osteoporotic fracture was calculated by dividing the number of first fractures occurring during follow-up by the number of person-years of follow-up (calculated as time from initial examination to the first fracture, end of study, death, or loss to follow-up). A similar rate was calculated for hip fractures only. The relationship between BMD and time to first osteoporotic fracture during follow-up was analyzed using Cox proportional hazards models. A similar analysis was attempted for hip fracture, although the study was powered only for osteoporotic fractures. When multiple fractures occurred at the first time point, only the first listed fracture diagnosis was included in analyses. Results were summarized using hazard ratios with 95% confidence intervals (CIs).

Proportional hazards assumptions were assessed by the interaction of time and BMD and by inspecting parallelism of estimated survival functions. Linearity of the relationship between standardized BMD and fracture risk was supported by nonsignificance of squared and cubic terms of BMD ( $P > .30$ ). Effect modification by key variables (age, fracture history, transfer status, and body mass index) was evaluated by including interaction terms in the model. Potential confounding was investigated by assessing whether the regression coefficient for BMD changed by more than 20% when individually adding variables (shown previously to be related to fracture and BMD) to a model with BMD only.<sup>27</sup>

**Table 1.** Baseline Characteristics of Study Sample (N = 1427)\*

Characteristics	Value
Age, y	
Mean (SD)	85 (7)
Range	65-104
MMSE score	
Mean (SD)	13.6 (9.8)
Moderately to severely impaired (score ≤18), No. (%)	913 (64)
Depressed (Cornell score ≥12), No. (%)	234 (16.4)
Fracture history, No. (%)	
Any	587 (41.1)
Hip	357 (25.0)
In past 6 mo	43 (2.9)
History of falls (≥1 in past 6 mo), No. (%)	1013 (71.0)
Comorbidity (Charlson Index score), No. (%)	
0	46 (3.2)
1	248 (17.4)
2	365 (25.6)
3	303 (21.2)
4	191 (13.4)
≥5	273 (19.1)
Impaired vision (significant field cut or legally blind), No. (%)	103 (7.2)
Psychotropic drug use, No. (%)	422 (29.6)
Body mass index, kg/m <sup>2</sup>	
Mean (SD)	23.9 (5.3)
Range	13-55
Grip strength, kg	
Mean (SD)	8.0 (6.7)
Range	0-90
Transfer independent, No. (%)†	528 (37.0)
Dependency in ≥3 ADLs‡	894 (65.4)
BMD§ of distal radius, g/cm <sup>2</sup>	
Mean (SD)	0.302 (0.07)
Range	0.128-0.549
Top quartile, mean (SD)	0.39 (0.04)
Bottom quartile, mean (SD)	0.22 (0.03)

\*MMSE indicates Mini-Mental State Examination; ADL, activities of daily living; and BMD, bone mineral density. Possible range for MMSE scores, 0-30; for Cornell scores, 0-38; and for Charlson scores, 0-37.

†Defined as moving to/from the bed, chair, or wheelchair without supervision.

‡Activities include dressing, eating, bathing, bed mobility, hygiene, and toileting. Dependency is defined as requiring extensive human assistance.

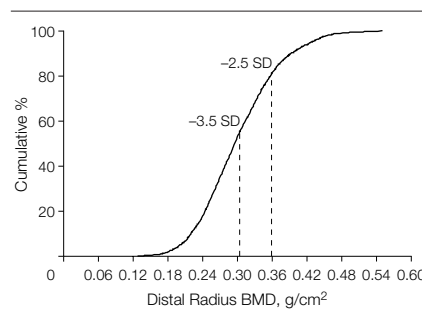
§The absorptiometer manufacturer's normal mean (SD) value for young women is 0.504 (0.058) g/cm<sup>2</sup>.

**RESULTS**

**Sample Characteristics**

Of 1953 eligible residents approached, 1456 (74.6%) agreed to participate. Twenty-nine women (2%) were lost to follow-up because of missing data or lack of access to medical records. Baseline characteristics of women lost to follow-up differed little from the 1427 women who were followed up (TABLE 1). At baseline, 71 residents (5%) were taking calcium and/or cholecalciferol; 28 (2%) were taking a prescription osteoporosis medication (such as estrogen);

**Figure 1.** Cumulative Distribution of Distal Radius Bone Mineral Density (BMD)



Measurement of BMD was performed in 1427 women. The absorptiometer manufacturer's mean (SD) normal value for young women is 0.504 (0.058) g/cm<sup>2</sup>.

**Table 2.** Osteoporotic Fractures in Nursing Home Residents

	No. With Fracture
First osteoporotic fracture during follow-up*	180
Rate (95% CI) per 1000 person-years	109 (93-125)
First hip fracture during follow-up†	75
Rate (95% CI) per 1000 person-years	44 (34-54)
Osteoporotic fractures by site, No. (%)	
Hip	84 (37.7)
Spine	33 (14.8)
Pelvis	11 (4.9)
Humerus	23 (10.3)
Wrist	25 (11.2)
Ribs	11 (4.9)
Leg (tibia/fibula)	14 (6.3)
Hand/feet/toes	18 (8.1)
Clavicle	4 (1.8)
<b>Total Osteoporotic Fractures‡</b>	<b>223</b>

\*Rate based on first osteoporotic fracture occurring during 1647 person-years of follow-up. CI indicates confidence interval.

†Rate based on first hip fracture occurring during 1718 person-years of follow-up. Includes multiple fractures in some individuals.

and 10 (0.7%) were taking calcium, cholecalciferol, and prescription osteoporosis medication. Overall, 89 residents (6.2%) were taking any osteoporosis treatment. Forty-three residents (2.9%) had a history of fracture in the past 6 months.

Mean (SD) and median BMD for this sample (0.302 [0.07] and 0.296 g/cm<sup>2</sup>) corresponds to a value of 3.5 SDs below the normal mean for young women (manufacturer's young-normal mean is 0.504 [0.058] g/cm<sup>2</sup>). Eighty-two percent of the sample had BMD values 2.5 SDs below or lower and 54% had val-

ues 3.5 SDs below or lower than the normal mean (FIGURE 1).

Four hundred forty-one (31%) of the 1427 residents died during the 18-month follow-up, with 45 (10%) of the deaths occurring following a fracture. Nineteen residents were transferred to another facility and 22 were discharged home during follow-up.

**Fractures**

During the 18 month follow-up period (1762 person-years), 223 osteoporotic fractures occurred among 180 women (TABLE 2). Twelve residents had more than 1 fracture on the same date and 38 patients had more than 1 fracture at different times during the 18 month follow-up. One hundred eighty women had at least 1 new osteoporotic fracture during follow-up, for an incidence rate of 109 per 1000 women per year (95% CI, 93-125).

A total of 84 hip fractures occurred during follow-up, accounting for 38% of total osteoporotic fractures. Nine residents had a second hip fracture during follow-up. Hence, 75 women had at least 1 new hip fracture during follow-up, for a rate of 44 hip fractures per 1000 women per year (95% CI, 34-54).

**Relationship of Individual Factors to Fracture**

When assessed univariately (without BMD in the model), age 85 years or older, history of fracture, and transfer independence were associated with a 30% to 60% increase in fracture (TABLE 3). By contrast, 3 or more comorbid conditions, history of falls in the past 6 months, and impaired vision were not associated with increased fracture. Dependence in 3 or more basic activities of daily living (bathing, dressing, eating, hygiene, bed mobility, or toileting), a variable strongly associated with dependence in transfer, was associated with an approximately 33% lower risk of fracture.

**BMD-Fracture Relationship**

Bone mineral density was a strong predictor of osteoporotic fracture (P<.001); fracture risk increased with lower BMD levels (Table 3). Nursing

home residents with values below the cohort median BMD (0.296 g/cm<sup>2</sup>, corresponding to 3.6 SDs below young peak normal) had a more than 2-fold increase in risk compared with women with values above the median (Table 3). Consistent with this finding, the cumulative incidence of fracture was higher in nursing home residents with BMD in the lower 2 quartiles of BMD than in those in the upper 2 quartiles (FIGURE 2). Using standardized BMD, fracture risk increased 40% for every SD decrease in BMD (TABLE 4).

When age, comorbidity, cognition, grip strength, depression, body mass index, falls in the past 6 months, fracture history, and psychotropic medication use at baseline were added to the model individually, the hazard ratio (HR) of fracture associated with BMD did not change more than 4%. Transfer independence, however, was significant when added to the BMD-fracture model ( $P < .001$ ) and there was suggestion of an interaction ( $P = .06$ ).

Nursing home residents independent in transfer had a more than 3-fold increase in risk of fracture (HR, 3.1; 95% CI, 2.2-4.4) if their BMD was below the median and a 90% increase in risk for every SD decrease in BMD (HR, 1.9; 95% CI, 1.5-2.4). Nursing home residents who were dependent in transfer had a 60% increase in risk of fracture if their BMD was below the median (HR, 1.6; 95% CI, 1.1-2.3) and a modest, nonsignificant elevation in fracture risk for every SD decrease in BMD (HR, 1.2; 95% CI, 0.98-1.4). Adjustment for age and other covariates separately or simultaneously did not change the fracture risk estimates for BMD by more than 8% in either transfer-independent or transfer-dependent residents (Table 4).

The rate of hip fracture was numerically higher in those with BMD below the median than in those with BMD above the median (53/1000 person-years [95% CI, 37-68] vs 35/1000 person-years [95% CI, 22-47], respectively). Risk of hip fracture was 2.5 times higher in those with BMD below than above the median among nursing home residents who were independent in transfer (HR, 2.5; 95%

**Table 3.** Rate of Fractures by Individual Factors\*

	No. of Women	Rate of Any Osteoporotic Fracture per 1000 Person-Years	Unadjusted Hazard Ratio (95% CI)†
Bone mineral density			
Above median	699	73	1.0
Below median	708	150	2.1 (1.5-2.8)
Age, y			
<85	603	90	1.0
≥85	824	124	1.4 (1.0-1.9)
History of fracture			
No	838	97	1.0
Yes	585	127	1.3 (0.97-1.8)
Transfer independence			
No	881	90	1.0
Yes	515	147	1.6 (1.2-2.2)
History of falls in past 6 mo			
No	412	138	1.0
Yes	1015	98	0.72 (0.53-0.97)
Comorbidity (Charlson score)			
<3	662	109	1.0
≥3	765	109	1.0 (0.75-1.4)
ADL dependency			
<3	474	142	1.0
≥3	894	92	0.66 (0.49-0.89)
Visual impairment			
No	1324	110	1.0
Yes	103	102	0.96 (0.53-1.7)

\*CI indicates confidence interval; ADL, activities of daily living. See the third footnote to Table 1 for definition of ADL dependency.

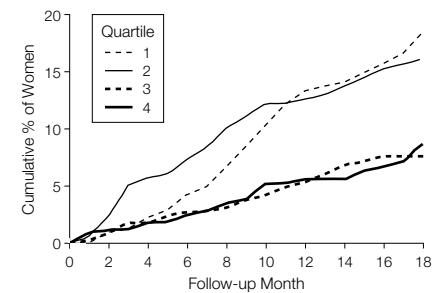
†Calculated using Cox proportional hazards models with each variable alone in model predicting fracture.

CI, 1.5-4.2), but not among residents dependent in transfer. Adjustment for age and other covariates did not change the risk of hip fracture associated with BMD by more than 12% in transfer-independent or transfer-dependent residents.

## COMMENT

We report the findings of the first large prospective study of the relationship between BMD and fracture in a sample of white women residing in a representative statewide sample of nursing homes. The findings demonstrate a strong relationship between low BMD and fracture in this population, even after accounting for other known risk factors. Importantly, although more than 80% of the sample had BMD values more than 2.5 SDs below young adult normal mean, and mean BMD levels in this population were lower than in community-dwelling white women of similar age,<sup>28</sup> a gradient with fracture rate greatest in the lower quartiles of BMD was still observed. Studies of

**Figure 2.** Cumulative Percentage of Residents With First Osteoporotic Fracture, by Bone Mineral Density (BMD) Quartile



Mean (SD) BMD values for the quartiles were: 0.222 (0.026) g/cm<sup>2</sup> for quartile 1, 0.276 (0.012) g/cm<sup>2</sup> for quartile 2, 0.32 (0.014) g/cm<sup>2</sup> for quartile 3, and 0.394 (0.04) g/cm<sup>2</sup> for quartile 4.

elderly community-dwelling white women support a strong link between low BMD and increased fracture risk, with at least a 50% increase in risk for every SD decrease in BMD, regardless of the site of BMD measurement.<sup>5-7</sup> Even in community-dwelling white women aged 80 years or older, mod-

**Table 4.** Risk of Any Osteoporotic Fracture Due to BMD\*

	Unadjusted Hazard Ratio (95% CI)	Adjusted Hazard Ratio (95% CI)
BMD per SD decrease	1.4 (1.2-1.6)	1.4 (1.2-1.6)†
BMD < median	2.1 (1.5-2.8)	1.9 (1.4-2.6)†
Transfer dependent		
BMD per SD decrease	1.2 (0.98-1.4)	1.15 (0.94-1.4)‡
BMD < median	1.6 (1.1-2.3)	1.4 (1.0-2.1)‡
Transfer independent		
BMD per SD decrease	1.9 (1.5-2.4)	1.9 (1.4-2.4)‡
BMD < median	3.1 (2.2-4.4)	2.9 (2.1-4.2)‡

\*BMD indicates bone mineral density; CI, confidence interval. See the second footnote to Table 1 for definition of transfer (in)dependency.

†Unstratified analysis additionally adjusted for transfer independence.

‡Adjusted for age, history of fracture, comorbidity, history of falls (past 6 months), and vision impairment. Adjustment for only age and history of fracture yielded a similar hazard ratio.

est reductions in BMD substantially increase fracture risk.<sup>28</sup>

We expressed the HR for fracture in terms of SD changes in BMD to facilitate comparison of these findings with those previously reported. However, the risk of fracture may not increase linearly with decreasing BMD across the entire range of BMD in this population. Nevertheless, it is clear that low BMD is a risk factor, even in the nursing home population, and the HR per SD change may be considered a reasonable estimate of average effect size.

This nursing home cohort showed a substantially higher rate of fractures, especially of the hip, than elderly community-dwelling white women.<sup>9,28</sup> The hip fracture rate of 44/1000 person-years in our cohort compares with 14.2/1000 person-years in community-dwelling women aged 80 years or older and 4.2/1000 person-years in women aged 65 to 79 years.<sup>27</sup> Wrist and humerus fracture rates in our cohort (14.4 and 13.2/1000 person-years, respectively) compare with rates of 10.2 and 6.4 in community-dwelling women aged 80 years or older and 7.4 and 3.4, respectively, in community-dwelling women aged 65 to 79 years.<sup>27</sup> The observed incidence rate of 109 osteoporotic fractures per 1000 person-years of follow-up is also higher than rates of 55 to 82 per 1000 person-years reported previously for nursing home populations.<sup>8</sup> It is possible that women in our sample were more impaired than nursing home residents in earlier studies be-

cause of the current shift toward alternate long-term care options for the less impaired. On the other hand, the fracture rates in this study may be underestimated due to exclusion of suspected fractures not documented by radiography or physician note. In addition, previous studies have been based primarily on single homogeneous nursing homes and may not be representative of nursing homes in general.

The most common fracture site was the hip, accounting for nearly 40% of the fractures in this cohort. This finding is slightly less than the 50% observed in prior nursing home studies,<sup>8,10</sup> possibly because of more complete ascertainment of less severe fracture types in this sample. The hip fracture rate in this study is 4 times higher than the rate found in elderly community-dwelling women aged 75 years or older.<sup>9</sup>

Transfer independence emerged as a strong independent predictor of fracture risk. Studies in smaller nursing home samples also have found higher fracture rates among ambulatory residents.<sup>10,29</sup> Intuitively, mobile nursing home residents have greater opportunity for falls (and fracture) than less mobile residents.<sup>22</sup> In a study of fall-related fractures among nursing home patients, more than a third of fractures occurred during a transfer activity.<sup>8</sup> Unlike in studies of community-dwelling populations, older age,<sup>7</sup> psychotropic medication use,<sup>10</sup> fracture history,<sup>30</sup> low body mass index,<sup>31</sup>

and poor cognition<sup>12</sup> were not independent predictors of fracture when added to the model containing BMD. Perhaps these factors are so prevalent in nursing home residents that they do not distinguish fracture risk as well as in healthier community-dwelling populations.

Independence in transfer and low BMD appear to be the strongest predictors of fracture in the nursing home, and the 2 operate synergistically to increase the risk of fracture. When residents who can transfer independently also have very low BMD, their risk of fracture more than triples compared with residents with relatively higher BMD levels. Even among residents requiring human assistance with transfer, those with the lowest BMD levels have a 60% higher risk of fractures than those with higher BMD levels.

Approximately 70% of fractures in this sample were the result of a fall. Information on the number of residents who fell but did not incur a fracture during follow-up was not available. Previous studies in community-dwelling populations have shown that, although most fractures result from falls, only a small percentage of falls (1%-6%) result in fracture.<sup>32</sup> Since low BMD contributes to the incidence of fracture among nursing home residents independent in transfer, relatively higher BMD levels may offer some protection against fracture.

We studied white women because of the high prevalence of osteoporosis and fracture in this group,<sup>33,34</sup> and because white women comprise more than two thirds of the US nursing home population.<sup>35</sup> Osteoporosis and fracture, though less prevalent, are important considerations among male and nonwhite nursing home residents<sup>17</sup> and should be evaluated in future studies. Few residents were being treated at baseline with medications that influence BMD or fracture risk; information about such medication use during follow-up was unavailable. It is possible that a small percentage of women initiated therapy after BMD results became known to their physicians. Hence, our BMD-fracture risk estimates may be conservative since

including treated residents would tend to dampen the BMD-fracture risk estimate.

This study was conducted in nursing homes in Maryland; it is unknown how these results generalize to other regions in the United States or worldwide. However, the nursing homes were drawn from a stratified representative sample of nursing homes in Maryland, and participants were comparable to the US nursing home popula-

tion in demographic and functional characteristics.<sup>17</sup>

## CONCLUSION

Low BMD and independence in transfer are significant predictors of osteoporotic fracture in nursing home residents. Whether interventions to increase BMD will lower the fracture rate among nursing home residents will require further study. Effective programs to modify these factors are needed to reduce over-

all nursing home fracture rates and the high costs of associated morbidity and health care utilization.

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