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Dima Alajlouni

Dana Bliuc

Thach Tran

Nicholas Pocock

Tuan Nguyen

See next page for additional authors

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Non standard lumbar region in predicting fracture risk

Upper lumbar spine and fracture risk

Dima Alajlouni[1]

Dana Bliuc[1]

Thach Tran[1]

Nicholas Pocock[1,6]

Tuan V Nguyen[1,2]

John A Eisman[1,2,3,4,5]

Jacqueline R Center[1,2,3]

[1]Osteoporosis and Bone Biology, Garvan Institute of Medical Research, Sydney, Australia

[2]Faculty of Medicine, University of New South Wales (UNSW) Australia, Sydney, Australia

[3]Clinical School, St Vincent's Hospital, Sydney, Australia

[4]Clinical Translation and Advanced Education, Garvan Institute of Medical Research, Sydney, Australia

[5]School of Medicine, University of Notre Dame Australia, Sydney, Australia

[6]Department of Nuclear Medicine, St. Vincent's Hospital, Sydney, New South Wales, Australia

Corresponding author:

Professor Jacqueline R Center

Garvan Institute of Medical Research

Email: j.center@garvan.org.au

ph: +61-2-92958271

fax: +61-2-92958241

Abstract

Background:

Femoral neck BMD is the most commonly used skeletal site to estimate fracture risk. The role of lumbar spine BMD in fracture risk prediction is less clear due to osteophytes that spuriously increase LS BMD, particularly at lower levels. The aim of this study was to compare fracture predictive ability of upper L1-L2 BMD compared to standard L2-L4 BMD and assess whether the addition of either lumbar spine site could improve fracture prediction over FN BMD.

Methodology:

A prospective cohort of 3016 women and men 60+ years from the Dubbo Osteoporosis Epidemiology Study followed for occurrence of minimal trauma fractures from 1989 to 2014. DXA was used to measure bone mineral density at f L1-L2, L2-L4 and FN at baseline. Fracture risks were estimated using Cox proportional hazards models separately for each site. Predictive performances were compared using ROC curve analyses.

Results:

There were 565 women and 179 men with a minimal trauma fracture during a mean of 11±7 years. L1-L2 BMD T-score was significantly lower than L2-L4 T-score in both genders ($p<0.0001$). L1-L2 and L2-L4 BMD models had a similar fracture predictive ability. LS BMD was better than FN BMD in predicting vertebral fracture risk in women [AUC 0. 73 (95% CI, 0.68-0.79) vs. 0.68 (95% CI, 0.62-0.74) but FN was superior for hip fractures prediction in both women and men. The addition of L1-2 or L2-4 to FN BMD in women increased overall

and vertebral predictive power compared to FN BMD alone by 1% and 4%, respectively ($P<0.05$).

Conclusion:

In an elderly population, L1-L2 is as good as but not better than L2-L4 site in predicting fracture risk. The addition of LS BMD to FN BMD provided a modest additional benefit in overall fracture risk. Further studies in individuals with spinal degenerative disease are needed.

Key Words

Osteoporosis; bone mineral density; fracture; fracture risk prediction; lumbar spine; femoral neck.

Introduction

Osteoporotic fracture is a common growing public health problem. The estimated number of fractures worldwide in 2000 was 8.96 million of which 61.3% occurred in women *(1)*. With the ageing population the global burden of osteoporosis and fracture is expected to increase together with the associated morbidity, mortality *(2, 3)* and health care costs *(1)*.

Bone mineral density (BMD) measured by dual-energy x-ray absorptiometry is the main tool to assess fracture risk *(4-6)*. It is better than total cholesterol for predicting cardiovascular disease and as good as hypertension for predicting stroke *(7)*. Clinical factors with or without BMD, including age, gender, prior fracture and falls among others are independent contributors to fracture risk *(8, 9)*.

Femoral neck (FN) BMD is the most commonly used site for fracture risk prediction *(10, 11)* because it gives similar fracture risk estimates in men and women and is not artificially elevated by osteoarthritis *(12)*. However, BMD measurements of both lumbar spine (LS) and femoral neck have been used for osteoporosis diagnosis and therapeutic decision making *(13)*. In one study, a combined LS and FN BMD site approach was associated with little benefit in fracture risk prediction *(14)* while, in another, selecting the lowest value from LS and FN BMD did not improve fracture prediction over a single site alone *(15)*.

A major reason why LS BMD is not as good as FN BMD at fracture risk prediction is because it is often affected by osteoarthritis. Osteoarthritis, a common condition in the elderly, spuriously elevates bone density. In Australia, 25% of women and men self-reported OA

(16). Thus LS BMD becomes increasingly unreliable in the elderly *(17)*. The upper lumbar spine is less prone to these arthritic changes than the lower lumbar spine *(18)*. Thus we hypothesised that measurement of the L1-L2 site may improve fracture risk prediction over the routinely used L2-L4 site. To our knowledge, there have not been any studies examining whether L1-L2 is a better predictor of fracture risk than L2-L4.

The aim of this study was to assess in a population of elderly women and men whether L1-L2 was i) a better fracture risk predictor, than L2-4 and ii) whether LS BMD added additional information to FN BMD in fracture risk prediction.

Methodology

Population and setting

The analysis was part of Dubbo Osteoporosis Epidemiology Study (DOES), the design and population of which have been described previously *(19)*. Briefly, people in the regional city of Dubbo, 400 km northwest of Sydney, Australia were invited to participate in this ongoing population based study in 1989. Data was collected during interviews approximately every second year. Dubbo was selected because of its stable population, relatively isolated medical care which made fracture ascertainment possible, and because the age and sex distribution of the population resembled that of the Australian population.

BMD and risk factors for osteoporosis were assessed prospectively. Informed consent was obtained from every participant and the study was approved by St Vincent's Hospital Research Ethics Committee.

Bone Mineral Density (BMD) measurement

All study participants had their BMD measured (g/cm^2), according to the manufacturer's guidelines at different skeletal sites (L1, L2, L3, and L4 lumbar spine and femoral neck). This was performed at baseline using dual-energy x-ray absorptiometry (DXA) (GE LUNAR, Madison, WI, USA). The coefficient of variation with this method for bone mineral density at our institution in normal subjects is 1.5% for the lumbar spine and 1.3% for the femoral neck. T-scores were obtained using the manufacturer's reference database.

Risk factors assessment and mortality

Baseline information was collected using a structured questionnaire. Information included history of falls and prior fracture, defined as fractures occurring at least 6 months prior to baseline. Measurements included anthropometry (height in metres and weight in kg), postural stability and quadriceps strength.

Mortality status was identified from systematic searches of funeral director lists, local newspapers, and Dubbo media reports and verified by death certificates from the New South Wales Registry of Births, Deaths and Marriages.

Ascertainment of Fractures

All fractures were confirmed through x-ray reports from the only two, and sometimes three, radiological centres in Dubbo as previously described *(20)*. The circumstances surrounding each fracture were obtained by telephone interview. The first incident low trauma fracture (fall from standing height or less) was the outcome of interest. Fractures were classified as any (any first osteoporotic fracture), hip, vertebral, and non-hip non-vertebral (NHNV) fractures. Vertebral fractures identified (from x-ray) were those coming to clinical attention. No systematic screening for vertebral fractures was performed at baseline or throughout the study. Fractures occurring following more than low trauma (e.g. motor accident, sporting injuries) and fractures of the head, finger and toe were excluded from the analysis as well as people with pathological fractures (malignancy and Paget's disease).

Statistical analysis

Follow up time was calculated from the first visit date to the occurrence of the first minimal trauma fracture, death, or end of study (December 2014). Incidence rates and 95% confidence intervals (CI) of fracture were calculated per 1000 person years assuming a Poisson distribution. Incidence rates were gender specific and calculated in 10-year age groups. The risk of osteoporotic fracture was assessed using gender specific Cox proportional hazard models. Four sets of models were constructed to investigate the risk of any, hip, vertebral and NHNV fractures. All variables, including L1-L2, L2-L4 and FN BMD, were tested in univariate and age-adjusted models. Bayesian Model Averaging approach *(21)* was used to select independent predictors for different BMD - models. Given that these predictors were BMD specific only age was included in the models for fracture performance comparison. The magnitude of fracture risk association for each continuous variable including BMD was presented as hazard ratios per 1 SD (higher/lower) and the corresponding 95% CIs. Schoenfeld residuals for each covariate in the model were plotted against time to exclude evidence for violation of the proportional hazards assumption.

In order to determine the role of each BMD measurement on fracture risk, age-adjusted Cox Proportional Hazards Models were constructed separately for each of the two LS BMD sites (gender and fracture type specific). The predictive performance for each of the models (L1-L2 and L2-L4) was assessed using Newson method *(22)*. The dataset was divided into two sub sets of equal size. Models were run in the first set, and Harrell's C-indexes with 95% CIs were estimated in the second set. C-index differences between models were then estimated with their 95% CIs to compare the predictive power between different models.

In order to determine whether the performance of the FN BMD model could be improved by the addition of any of the LS measurements, separate age adjusted Cox Proportional Hazards Models including L1-L2 and FN BMD as well as L2-L4 and FN BMD were compared to the age adjusted model containing FN BMD alone. The predictive powers of these models were estimated and compared using Newson method.

A two-sided P value < 0.05 was considered statistically significant. All statistical analyses were performed using Stata statistical software package 13 (Stata Corporation, College Station, TX, USA).

Results

There were 1839 women and 1163 men with a mean age of 69 years who were followed up for a mean of 11±7 years. The mean L1-L2 T-score was significantly lower than that of L2-L4 T-score in women (-1.4 vs. -1.0, P<0.0001) and men (-0.1 vs. +0.6, P<0.0001). During the follow-up 565 women and 179 men sustained at least one minimal trauma fracture. Of all the fractures, there were 78 (14%) hip fractures in women and 27 (15%) in men, 205 (36%) clinical vertebral fractures in women and 74 (41%) in men and 282 (50%) non-hip non-vertebral fractures in women and 78 (44%) in men. As expected, fracture incidence rates were higher in women (27/1000 person-years; 95% CI: 25.4 - 30.0) than in men (13.5; 95% CI: 11.7 - 15.6) over the entire age range. The incidence rate of fracture increased with age, 22.9, 34.5 and 63.2/1000 person years in women aged 55–70, 70-80, and 80+ years respectively. The corresponding rates for men were 10.7, 19.6, and 23.6/1000 person-years.

Participants with fracture were significantly older, had lower weight, lower quadriceps strength, and more likely to die compared to those without fracture (Table 1). All BMD measurements were significantly lower in the fracture population.

A decrease in BMD at any of the sites was associated with 22-57% increased risk of any osteoporotic fracture in women and men (P<0.0001) (Table 1). The strongest association with fracture risk was observed for FN BMD [HR per SD decline, 1.55 (95% CI; 1.43 - 1.69) for women and 1.57 (95% CI; 1.37 - 1.80) for men. Notably, both L1-2 and L2-4 BMD were significantly associated with fracture risk in both women [HR per SD, 1.33 (95% CI; 1.25 -

1.42) and 1.28 (95% CI; 1.21 - 1.36) for L1-L2 and L2-L4, respectively] and men [HR per SD, 1.22 (95% CI; 1.11 - 1.34) and 1.22 (95% CI; 1.11 - 1.33) for L1-L2 and L2-L4, respectively].

After adjusting for age, the magnitude of association with any fracture remained higher for FN BMD than LS BMD (Table 2). FN BMD also had significantly higher magnitude of association with hip fracture prediction than any of the LS BMD sites, while all sites were significantly associated with vertebral fracture risk prediction with a similar magnitude of association in both women and men. All BMD sites were significantly associated with increased risk of NHNV fracture in women while none of the BMD sites was significantly associated with NHNV fracture risk in men (Table 2).

Comparison between L1-L2 and L2-L4 models in fracture prediction

Both L1-L2 and L2-L4 were comparable in fracture prediction for all, hip, vertebral and NHNV fractures in both women and men with AUCs ranging from 0.65 (95% CI; 0.61 – 0.69) in women and 0.62 (95% CI; 0.56 – 0.68) in men for all fractures to 0.73 (95% CI; 0.68 – 0.79) in women and 0.72 (95% CI; 0.61 – 0.83) in men for vertebral fracture prediction (Table 2). These AUCs were similar to FNBMD models for all fractures and NHNV fracture models. However, as expected FN BMD had the best predictive ability for hip fracture in women and men ($P<0.001$ in women and $p=0.02$ in men) while spine BMD (either L1-L2 or L2-L4) had better predictive ability for vertebral fracture in women ($P=0.003$) (Table 2).

Contribution of L1-L2 and L2-L4 to FN BMD in fracture risk prediction

In women, the addition of either L1-L2 or L2-L4 BMD to FN BMD alone significantly but marginally improved the prediction of any fracture (AUC 0.65 vs. 0.64, $p= 0.047$ for L1-L2

and 0.65 vs. 0.6, p= 0.03 for L2-L4) (Table 3). Similarly, both lumbar spine models when added to FN BMD resulted in better predictive power than FN BMD alone for vertebral fracture prediction (AUC 0.72 vs. 0.68, p=0.03 for L1-L2 and 0.72 for L2-L4, p=0.04). On the other hand and as expected, neither L1-L2 nor L2-L4 improved the prediction power of hip fractures over FN BMD alone.

In men, the addition of either L1-L2 or L2-L4 over FN BMD alone did not improve fracture prediction for any site.

Discussion

This study compared the fracture risk prediction of L1-L2, L2-L4, and FN BMD sites in a population of older women and men. L1-L2 BMD T-score was significantly lower than L2-L4 consistent with the hypothesis that the lower spine is more affected by osteoarthritis than the upper spine. Despite this finding, the fracture predictive power was similar for these two lumbar spine sites. The ability of L1-L2 and L2-L4 BMD to predict fracture risk was comparable in both genders and across different fracture types.

In comparison with FN BMD, both LS BMD measurements were significantly better than FN BMD for vertebral fracture prediction in women but not men, while FN BMD was the best predictor of hip fractures for both genders. For prediction of any fracture and NHNV fracture, all 3 BMD measurements (L1-L2, L2-L4, and FN) were comparable. The addition of either L1-L2 or L2-L4 to FN BMD contributed significantly to the overall and vertebral fracture risk prediction in women only.

Degenerative diseases, which spuriously increase LS BMD, predominantly affect the lower lumbar spine. Facet joint osteoarthritis, for example is more prevalent at L4-L5 (45%) than L2-L3 (15%) *(18)*. This is the first study to our knowledge to compare fracture risk prediction of the upper L1-L2 with the standard L2-L4 BMD. The reduced diagnostic sensitivity of the lower LS L4 vertebra due to degenerative changes compared to the higher individual L1, L2, and L3 vertebrae was previously explored by Ryan et al. *(23)* who examined the variability of different LS BMDs and found that L4 had lower diagnostic sensitivity compared with other individual vertebrae.

The findings from the current study are consistent with several studies in the literature including a meta-analysis of 11 studies and more than 2000 fractures *(5, 7, 24)*. In this meta-analysis, all BMD sites were associated with a similar fracture predictive power with a narrow variation of 1.4 to 1.6 fold increase in fracture risk per 1 SD lower BMD. However, similar to the current study, LS BMD was the best predictor for vertebral fracture [RR 2.3 (95% CI; 1.9 – 2.8) and hip BMD for hip fracture [RR 2.6 (95% CI; 2.0 – 3.5).

In the clinical setting and in different fracture risk calculators, FN BMD is the predominant or sole site used to assess osteoporosis. However, it is unclear how to address situations when FN BMD measurement cannot be used, as a result of hip surgery (e.g. bilateral hip replacement), or when there is a discordance between FN and LS BMD *(25-28)*. These conditions are not infrequent and it would be expected that fracture risk prediction would be improved in these cases if lumbar spine BMD were used or incorporated in fracture risk calculators.

This study thus examined the value of adding LS to FN. The addition of either L1-L2 or L2-L4 BMD measurement to the FN BMD model contributed significantly to the overall fracture risk prediction compared to the FN model alone in women. AUCs improved significantly, albeit modestly; the addition of L1-L2 BMD resulted in a 1.0% improvement for any fracture (p=0.05) and 4.0% improvement in vertebral fracture (p=0.03) while the addition of L2-L4 was associated with a 1.0% improvement for any fracture (p=0.03) and 4.0% improvement in vertebral fracture (P=0.04). These findings are consistent with previous reports that

adding LS BMD to FN BMD enhanced overall fracture *(29)* and vertebral fracture prediction *(24, 29)*.

This study has number of strengths. It is a large prospective study with long follow up time (26 years). All fractures were confirmed by x-ray reports. Robust analysis methods were used to look at both strength of association and prediction power of different models. However, this study has a few limitations. Artefacts or deformities were not specifically assessed, and the small numbers of fractures in men limited the reliability of their estimates. Furthermore, the results may not be generalised in all ethnic groups as the population was predominantly Caucasian.

In summary, this study addressed an important clinical question regarding the use of L1-2 instead of L2-4 BMD in predicting fracture risk in an effort to overcome the effect of degenerative changes in the spine. However, despite the fact that L1-L2 BMD T-score was significantly lower than L2-L4 T-score, suggesting that the former may be less affected by OA, at a population level there was no difference between these sites in predicting fracture risk. Both LS sites had a similar predictive ability to FN in the prediction of all and NHNV fractures, and were superior to FN for vertebral but not hip fracture prediction. The addition of either of the LS BMD sites to FN BMD added modestly to the prediction of overall fracture risk in women. However, FN BMD remained the best predictor for hip fracture.

Conclusion

Although L1-L2 had lower BMD T-score than L2-L4, it did not improve fracture risk prediction at a population level. Further studies are needed to determine the role of L1-L2 or measurements of specific vertebrae in individuals with degenerative disease of the spine.

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Authors' roles:

Study design: DA, DB, TT, NP, TVN, JAE, and JRC. Data collection: DA, TVN, JAE, and JRC. Data analysis and interpretation: DA, DB, TT, JAE, and JRC. Manuscript drafting: DA, DB, TT, and JRC. Revising manuscript content: DB, TT, NP, JAE, and JRC. Approving final version of manuscript: DA, DB, TT, NP, TVN, JAE, and JRC.

Table (1): Baseline characteristics and crude hazard ratios (n= 3016)

Characteristics	No Fracture	Fracture	Unit of change	Hazard ratios (95% CI)
Women (1839)				
Number	1274 (69.3)	565(30.7)		
Age (years) [a]	68.6 (6.3)	69.8 (6.7)[c]	+5 years	1.28 (1.20 - 1.37)
Weight (kg) [a]	68.9 (13.6)	65.6 (12.3)[c]	-5 kg	1.07 (1.03 - 1.11)
Height (cm) [a]	160.2 (5.9)	160.0 (6.7)	-5 cm	1.05 (0.99 - 1.14)
L1-L2 BMD g/cm^2 [a]	1.02 (0.18)	0.93 (0.17)[c]	-0.12 g/cm^2	1.33 (1.25 - 1.42)
L1-L2 T-score [a]	-1.2 (1.4)	-1.9 (1.4)[c]		
L2-L4 BMD g/cm^2 [a]	1.10 (0.20)	1.01 (0.20)[c]	-0.12 g/cm^2	1.28 (1.21 - 1.36)
L2-L4 T-score [a]	-0.8 (1.6)	-1.6 (1.6)[c]		
FN BMD g/cm^2 [a]	0.84 (0.14)	0.77 (0.12)[c]	-0.12 g/cm^2	1.55 (1.43 - 1.69)
FN T-score [a]	-1.4 (1.1)	-1.9 (1.0)[c]		
Quadriceps strength (kg) [a]	21.7 (8)	20.2 (7)[c]	-5 kg	1.16 (1.10 - 1.23)
Prior fracture (Y,N) [b]	76 (6)	36 (7)	Yes	1.44 (1.03 - 2.02)
Deceased (Y,N) [b]	370 (29)	271 (48)[c]		
Falls (Y,N) [b]	412 (32)	195 (34)	Yes	1.23 (1.03 - 1.46)
First Fracture type				
Hip [b]		78 (14)		
Vertebral [b]		205 (36)		
NHNV [b]		282 (50)		
Men (1163)				
Number	984 (84.6)	179 (15.4)		
Age (years) [a]	69.1 (5.6)	70.5 (6.3)[c]	+5 years	1.37 (1.22 - 1.55)
Weight (kg) [a]	81.8 (13.6)	78.4 (12.4)[c]	-5 kg	1.08 (1.01 - 1.14)
Height (cm) [a]	173.5 (6.8)	172.9 (6.4)	-5 cm	1.09 (0.98 - 1.22)
L1-L2 BMD g/cm^2 [a]	1.20 (0.20)	1.13 (0.18)[c]	-0.12 g/cm^2	1.22 (1.11 - 1.34)
L1-L2 T-score [a]	-0.003 (1.7)	-0.5 (1.5)[c]		
L2-L4 BMD g/cm^2 [a]	1.28 (0.22)	1.20 (0.20)[c]	-0.12 g/cm^2	1.22 (1.11 - 1.33)
L2-L4 T-score [a]	0.7 (1.8)	-0.02 (1.7)[c]		
FN BMD g/cm^2 [a]	0.94 (0.14)	0.87 (0.15)[c]	-0.12 g/cm^2	1.57 (1.37 - 1.80)
FN T-score [a]	-0.8 (1.2)	-1.4 (1.2)[c]		
Quadriceps strength (kg) [a]	36.2 (10)	34.6 (10)[c]	-5 kg	1.13 (1.05 - 1.22)
Prior fracture (Y,N) [b]	41 (4)	9 (5)	Yes	1.42 (0.73 - 2.78)
Deceased (Y,N) [b]	405 (41)	110 (62)[c]		
Falls (Y,N) [b]	313 (32)	62 (35)	Yes	1.20 (0.88 - 1.64)
First Fracture type				
Hip [b]		27 (15)		
Vertebral [b]		74 (41)		
NHNV [b]		78 (44)		

[a] Continuous variables were expressed as mean (SD)

[b] Categorical variables were expressed as number (percentage)

[c] $P \leq 0.05$ (Significant difference between fractured and non-fractured groups).

Table (2): Fracture prediction at different BMD sites

Site measurement (g/cm^2)	Hazard ratio (95% CI)	%AUC (95% CI)
Women		
Any fracture	N= 565	
L1-L2 BMD	1.29 (1.21 - 1.37)	65.05 (61.37 – 68.72)
L2-L4 BMD	1.26 (1.19 - 1.33)	64.96 (61.39 – 68.53)
Femoral neck BMD	1.45 (1.33 - 1.58)	64.41 (60.80 – 68.02)
Hip fractures	N=78	
L1-L2 BMD	1.21 (1.02 - 1.43)	72.59 (64.00 – 81.19)[a]
L2-L4 BMD	1.13 (0.97 - 1.31)	71.21 (62.31 – 80.11)
Femoral neck BMD	2.11 (1.64 - 2.71)	83.25 (78.48 – 88.02)
Vertebral fractures	N=205	
L1-L2 BMD	1.53 (1.37 - 1.71)	72.96 (67.57 – 78.36)
L2-L4 BMD	1.52 (1.37 - 1.68)	73.44 (68.22 – 78.67)
Femoral neck BMD	1.42 (1.23 - 1.64)	67.92 (62.24 – 73.60)
NHNV fractures	N=282	
L1-L2 BMD	1.26 (1.15 - 1.38)	62.37 (57.14 – 67.60)
L2-L4 BMD	1.24 (1.14 - 1.35)	62.87 (57.72 – 68.02)
Femoral neck BMD	1.47 (1.30 - 1.66)	63.05 (58.07 – 68.03)
Men		
Any fracture	N=179	
L1-L2 BMD	1.20 (1.09 – 1.32)	62.48 (56.48 – 68.49)
L2-L4 BMD	1.21 (1.11 – 1.32)	63.43 (57.52 – 69.34)
Femoral neck BMD	1.47 (1.28 – 1.69)	64.49 (58.45 – 70.52)
Hip fractures	N= 27	
L1-L2 BMD	1.12 (0.90 - 1.39)	74.50 (61.06 – 87.94)
L2-L4 BMD	1.12 (0.91 - 1.37)	74.50 (61.11 – 87.88)
Femoral neck BMD	2.36 (1.60 - 3.48)	82.40 (70.74 – 94.06)
Vertebral fractures	N= 74	
L1-L2 BMD	1.37 (1.18 - 1.59)	69.35 (59.18 – 79.53)
L2-L4 BMD	1.37 (1.19 - 1.57)	71.90 (60.79 – 83.02)
Femoral neck BMD	1.77 (1.42 - 2.20)	72.35 (61.71 – 83.00)
NHNV fractures	N= 78	
L1-L2 BMD	1.10 (0.96 - 1.27)	59.20 (49.58 – 68.83)
L2-L4 BMD	1.13 (1.00 - 1.29)	59.08 (50.16 – 68.00)
Femoral neck BMD	1.16 (0.95 - 1.43)	64.97 (56.04 – 73.90)

All models were age adjusted.

Hazard ratios were presented for every 1 SD decrease in each BMD measurement.

[a] L1-L2 model was significantly better than L2-L4 model (P = 0.002).

Table (3): Model improvement with Addition of LS to FN BMD in fracture prediction

Model	AUC (95% CI)	
	Women	Men
Any fracture		
FN	64.41 (60.80 – 68.02)	64.49 (58.45 – 70.52)
FN and L1-L2	65.18 (61.57 – 68.79)	64.79 (58.77 – 70.80)
P[a]	0.05	0.54
FN and L2-L4	65.35 (61.77 – 68.94)	65.22 (59.30 – 71.14)
P[b]	0.03	0.30
Hip fracture		
FN	83.25 (78.48 – 88.02)	82.40 (70.74 – 94.06)
FN and L1-L2	81.37 (76.36 – 86.39)	82.06 (70.02 - 94.09)
P[a]	0.13	0.83
FN and L2-L4	80.89 (75.36 – 86.43)	82.21 (70.60 - 93.83)
P[b]	0.13	0.87
Vertebral fracture		
FN	67.92 (62.24 – 73.60)	72.35 (61.71 – 83.00)
FN and L1-L2	72.04 (66.60 – 77.48)	72.15 (61.71 – 82.59)
P[a]	0.03	0.91
FN and L2-L4	72.38 (67.10 – 77.66)	73.05 (62.43 – 83.68)
P[b]	0.04	0.68
NHNV fracture		
FN	63.05 (58.07 – 68.03)	64.97 (56.04 – 73.90)
FN and L1-L2	63.41 (58.37 – 68.44)	59.13 (49.51 – 68.74)
P[a]	0.45	0.08
FN and L2-L4	63.44 (58.44 – 68.44)	56.65 (47.44 – 65.85)
P[b]	0.17	0.06

All models were age adjusted.

[a] P: Significance of the AUC difference between FN with L1-L2 models and FN alone models.

[b] P: Significance of the AUC difference between FN with L2-L4 models and FN alone models.

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