Age and Ageing 2009; **38:** 429–434
doi: 10.1093/ageing/afp051
Published electronically 30 April 2009

Risk factors for hip fracture among institutionalised older people

JIAN SHENG CHEN[1], PHILIP N. SAMBROOK[1], JUDY M. SIMPSON[2], IAN D. CAMERON[3], ROBERT G. CUMMING[4], MARKUS J. SEIBEL[5], STEPHEN R. LORD[6], LYN M. MARCH[1]

[1]Institute of Bone and Joint Research, University of Sydney, Royal North Shore Hospital, St Leonards NSW 2065, Australia
[2]Department of Public Health & Community Medicine, University of Sydney, Sydney NSW 2006, Australia
[3]Rehabilitation Studies Unit, University of Sydney, Ryde NSW 2112, Australia
[4]Centre for Education and Research on Ageing, University of Sydney, Concord NSW 2139, Australia
[5]Anzac Research Institute, University of Sydney, Concord Hospital, Concord NSW 2139, Australia
[6]Prince of Wales Medical Research Institute, UNSW, Barker St, Randwick NSW 2031, Australia

Address correspondence to: J. S. Chen. Tel: (+61) 2 9926 7328; Fax: (+61) 2 9906 1859. Email: jschen@med.usyd.edu.au

Abstract

Background: risk factors for hip fracture in community-dwelling individuals have been extensively studied, but there have been fewer studies of institutionalised older people.

Methods: a total of 1,894 older people (1,433 females, 461 males; mean age 86 years, SD 7.1 years) were recruited from 52 nursing homes and 30 intermediate-care nursing care facilities in Australia during March 1999 and February 2003. We assessed clinical risk factors for hip fracture and skeletal fragility by calcaneus broadband ultrasound attenuation (BUA) at baseline and then followed up for fracture for 4 years. Hip fractures were validated by x-ray reports. Survival analysis with age as a time-dependent covariate was used to analyse the data.

Results: during a mean follow-up period of 2.65 years (SD 1.38), 201 hip fractures in 191 residents were recorded, giving an overall hip fracture incidence rate of 4.0% per person year (males 3.6% and females 4.1%). Residents living in intermediate-care hostels had a higher crude hip fracture rate (4.6% vs. 3.0%) than those living in high-care nursing homes. In multivariate analysis, an increased risk of hip fracture was significantly associated with older age, cognitive impairment, a history of fracture since age 50, lower body weight, longer lower leg length and poorer balance in intermediate-care hostel residents, but not with lower BUA.

Conclusions: institutionalised older people, who are at a higher risk of hip fracture than community-dwelling individuals, have differences in some risk factors for hip fracture that should be considered in targeting intervention programs.

Keywords: *hip fracture, risk factors, aged, aged-care facilities, elderly*

Introduction

About 20% of older people who suffer a hip fracture die in the first year and most of the survivors do not fully recover [1, 2]. In Australia, the lifetime risk of hip fracture at the age of 50 years was estimated to be 17.7% in women and 6.3% in men [3]. The incidence of hip fractures increases exponentially beyond the age of 60 years [4, 5] and in institutionalised older people, can be as high as 6.2% and 4.9% per annum for females and males, respectively [6]. Institutionalised older people have increased high levels of chronic illness, medication use, cognitive disorders and impairments of vision, strength and neuromuscular functioning. They also have a high prevalence of falls and low bone strength.

In community-dwelling people, the risk of hip fracture has been shown to be associated with low bone strength, female gender, older age and clinical factors such as a maternal family history of hip fracture, a history of previous fractures, being tall at age 25, previous hyperthyroidism, diabetes mellitus, use of psychotropic medications, greater caffeine use and postural instability [5, 7, 8]. Risk factors for hip fracture in elderly people living in aged-care facilities have been less well studied [9, 10] despite the fact that ∼40% of all hip fractures occur in this population [11, 12].

In this study, we examined the associations of hip fracture with BUA and clinical risk factors in a large cohort of elderly men and women living in high-care nursing homes and intermediate-care hostels.

Methods

Study design

The Fracture Risk Epidemiology in the frail Elderly (FREE) study is a prospective cohort study designed to evaluate risk factors for falls and fractures [13, 14]. All aged-care facilities in the Northern Sydney Health Services area (Sydney, Australia) were randomly assigned to blocks of 10 nursing homes and 5 intermediate-care hostels. The institutions were approached block by block. In total, 2,005 subjects from 52 nursing homes and 30 intermediate-care hostels were recruited from March 1999 to February 2003. The participation rate was 88% for institutions and 55% for individuals. For non-participants (either personally or through carer advice), some demographic details were collected before introduction of laws that restricted access to residents' information in 2002. The non-participants were similar in age and gender to the participants, but had higher care needs and hence a greater likelihood of living in a nursing home. Individuals who were bed bound, bilateral amputees, non-English speaking or under the age of 65 years were excluded. Ethics approval for the study was given by the Human Research Ethics Committee at the Northern Sydney Area Health Service. Informed consent for participation was obtained from residents or persons legally able to give consent on their behalf.

Study subjects

For this analysis, 111 subjects were excluded due to having bilateral total hip replacements at baseline ($n = 44$), answering yes to the question of total hip replacement but not recording whether it was one or both legs ($n = 50$) or not answering the question of total hip replacement ($n = 17$). Of the remaining 1,894 study subjects, 461 were males and 1,433 were females.

Baseline assessments

Risk factors that were assessed at baseline by interview or medical record review included age, sex, type of residence (nursing home or intermediate-care hostel), comorbidities assessed using a modification of the Implicit Illness Severity Rating Scale (IISC) [15], cognitive function by Standardized Mini Mental State Examination (SMMSE) [16], use of walking aids, presence of urinary incontinence, medication use, joint replacements (knee and hip), history of Parkinson's disease, stroke, history of smoking, previous fracture since age 50 and falls in the past 12 months.

Static balance was assessed using a balance test [17] simplified for this population. Subjects were classified into five grades as follows: 1 = unable to stand on a firm surface for any period of time without support from another person or use of a walking aid, 2 = unable to maintain balance on a firm surface for 30 s, 3 = capable of maintaining balance on a firm surface for 30 s but unable to maintain balance on a yielding foam rubber mat (70 cm × 60 cm × 15 cm thick) for any period of time, 4 = capable of maintaining balance on a firm surface but unable to maintain balance on the foam rubber mat for 30 s and 5 = capable of maintaining balance for 30 s each when standing on a firm surface and on the foam mat. Weight was measured in bare feet with light clothes on. Height or height loss could be an important risk factor for fractures among the study population. However, it is not possible to obtain information on height at age 20 years from residents with cognitive impairment and is also very difficult to measure height among those residents with limited standing abilities. Lower leg length was measured from floor to knee (bent at 90°) as an index of mature skeletal stature [18]. Serum levels of 25-hydroxyvitamin D (25(OH)D) and intact parathyroid hormone (PTH) were also measured among residents who gave consent for venesection.

Bone fragility was assessed by quantitative ultrasound (QUS). This is because it is difficult to obtain bone mineral density (BMD) using dual energy x-ray absorptiometry in such a frail elderly population even though the femoral neck BMD T-score is the best overall predictor of hip fracture risk. BUA (a QUS parameter) was measured in the calcaneus using a McCue Cuba Mark II machine. BUA was determined from the mean of replicate left heel measurements, the second obtained with repositioning. In a previous study, we reported that a BUA value of 67.4 dB/MHz corresponded to a femoral neck BMD T-score of −2.5 [19].

Follow-up

All residents were followed up for hip fracture or death through regular liaison (every 6–12 weeks) with the residential care facilities. Hip fractures were validated by x-ray reports. Only 15 residents were lost to follow-up during the study period.

Statistical analysis

Survival analysis was chosen to analyse the data, and the Andersen and Gill model was used to account for second hip fractures. Residents contributed follow-up time until their second hip fracture (or first hip fracture if a total hip replacement was recorded at baseline), death, date of loss to follow-up or 4 years since baseline, whichever occurred first. Age was treated as a time-dependent variable. Follow-up time was censored at 4 years to maintain the validity of the proportional hazards assumption for all other variables, which were measured only at baseline. Martingale residuals were used to assess whether continuous covariates should be modelled as continuous or categorised.

In the model selection, a backward elimination approach was used to drop out non- significant terms with the highest *P*-value progressively until all terms remaining were significant ($P<0.05$, two-sided). Terms that were removed were added to the final model one at a time to assess their significance. *P*-values were obtained from the partial likelihood ratio test. Effect modification for type of residence was tested by including interaction terms with type of residence. If there was a significant interaction, a single new variable was created to reflect the fact that the effect of one variable was modified by the other.

Table 1. Baseline characteristics of the residents by subsequent hip fracture status

	No. of subjects measured	Subjects without new hip # ($N = 1,703$)	Subjects with new hip # ($N = 191$)
Age (year), mean (SD)	1,894	85.4 (7.1)	86.6 (6.4)
Female, number (%)	1,894	1,280 (75.2)	153 (80.1)
Type of residence: hostel, number (%)	1,894	939 (55.1)	136 (71.2)
BUA (dB/MHz), mean (SD)	1,866	52.2 (22.6)	50.4 (17.6)
Weight (kg), mean (SD)	1,777	60.5 (14.4)	57.7 (12.5)
Lower leg length (cm), mean (SD)	1,847	50.7 (3.0)	50.6 (3.1)
SMMSE[a], mean (SD)	1,885	20.4 (8.9)	20.9 (8.1)
Past fall, number (%)	1,841	865 (52.3)	96 (51.3)
Previous fracture, number (%)	1,877	772 (42.8)	104 (54.7)
Current smoker, number (%)	1,891	90 (5.3)	10 (5.3)
History of smoking, number (%)	1,874	638 (37.8)	69 (36.9)
'Bone-active' medication[b], number (%)	1,890	334 (19.7)	42 (20.0)
No. of medications ≥ 7, number (%)	1,890	796 (46.6)	82 (42.9)
Urinary incontinence, number (%)	1,862	1,013 (60.3)	99 (54.1)
Parkinson's disease, number (%)	1,867	104 (6.2)	9 (4.7)
Stroke, number (%)	1,838	377 (22.8)	36 (19.1)
Total knee replacement, number (%)	1,887	102 (6.0)	14 (7.3)
Total hip replacement, number (%)	1,894	139 (8.2)	7 (3.7)
Balance (grade), number (%)	1,882		
1		346 (20.5)	10 (5.2)
2		184 (10.9)	22 (11.5)
3		299 (17.7)	41 (21.5)
4		366 (21.6)	56 (29.3)
5		496 (29.3)	62 (32.5)
Walking aids, number (%)	1,879		
Unaided		503 (29.8)	72 (38.1)
Uses a stick		370 (21.9)	51 (27.0)
Uses frame		534 (31.6)	59 (31.2)
Wheelchair		283 (16.7)	7 (3.7)
IISC[c], number (%)	1,872		
No symptoms		66 (3.9)	1 (0.5)
Mild symptoms		435 (25.9)	75 (39.3)
Moderate symptoms		1,122 (66.7)	109 (57.1)
Seriously ill		58 (3.5)	6 (3.1)
25(OH)D (nmol/l), mean (SD)	1,213	29.0 (16.6)	30.6 (15.0)
Parathyroid hormone (pg/ml), median (interquartile range)	1,212	58.1 (37.2–92.1)	58.9 (37.2–90.9)

[a]Standardized Mini Mental State Examination; [b]'Bone-active' medication—use of any vitamin D preparation, calcium, hormone therapy or bisphosphonates; [c]IISC—the Implicit Illness Severity Rating Scale.

Results

The 1,894 participants had a mean age of 85.6 years (range: 65–104) and 75.7% were female. In general, they had low bone strength as suggested by a mean BUA value of 52.0 (SD 22.2) dB/MHz, and by 44.0% of all subjects having a history of fracture since age 50. Similarly, most residents were frail with 70.4% having a static balance grade <5, 69.4% using a walking aid, 50.3% showing some degree of cognitive impairment (SMMSE < 24) and 43.2% living in nursing homes. The baseline characteristics of the participants by hip fracture status are presented in Table 1.

During a mean follow-up period of 2.65 years (SD 1.38), 201 hip fractures were recorded in 191 residents, giving an overall hip fracture incidence rate of 4.0% per person year. The crude hip fracture rate was 3.6 and 4.1% for males and females, respectively. Residents living in intermediate-care hostels were more mobile (62.2% used a walking aid vs. 79.0% in nursing homes) and healthier (56.4% had IISC rating worse than mild symptoms vs. 86.1%) but had a higher crude hip fracture rate (4.6% vs. 3.0%) than those living in nursing homes.

In univariate analysis, the risk of hip fracture was significantly associated with older age, lower weight and better static balance. The risk of hip fracture was higher in intermediate-care residents, in subjects without a total hip replacement and in those who were able to walk (Table 2). Significant risk factors also included a self-reported history of fracture since age 50 and the presence of comorbidities. Participants with intermediate values of BUA appeared to have higher risk of hip fracture than those with low or high values.

Multivariate analysis showed that the effect of static balance on the risk of hip fracture was modified by type of residence ($P = 0.04$) with a greater risk of hip fracture being associated with poorer balance in intermediate-care hostels but better balance in nursing homes. Other independent risk

Table 2. Hazard ratios (HRs) for potential risk factors for hip fracture from univariate analysis

Variable	HR (95% CI)	*P*	Variable	HR (95% CI)	*P*
Age[a] (year)		0.001	No. of medications ≥ 7	0.95 (0.72–1.26)	0.72
≥90	2.08 (1.32–3.28)		Urinary incontinence	0.81 (0.61–1.07)	0.14
85–89	1.81 (1.13–2.91)		Parkinson's disease	0.77 (0.40–1.46)	0.42
80–84	1.06 (0.61–1.84)		Stroke	0.82 (0.58–1.17)	0.28
65–79	1.00		Total knee replacement	1.17 (0.68–2.00)	0.57
Female	1.17 (0.83–1.66)	0.38	Total hip replacement	0.45 (0.21–0.96)	0.04
Type of residence: hostel	1.52 (1.12–2.06)	0.008	Balance (grade)		<0.001
BUA (dB/MHz)		0.01	5	3.01 (1.56–5.81)	
<39.7	1.22 (0.84–1.78)		2–4	3.75 (1.99–7.07)	
39.7–<58.9	1.66 (1.17–2.35)		1	1.00	
≥58.9	1.00		Walking aids		0.005
Weight (kg)		0.003	Wheelchair	0.25 (0.12–0.54)	
27–52	1.82 (1.26–2.63)		Uses frame	0.87 (0.62–1.21)	
53–64	1.76 (1.22–2.53)		Uses a stick	0.93 (0.66–1.33)	
≥65	1.00		Unaided	1.00	
Lower leg length ≥ 50.5 cm	1.06 (0.80–1.40)	0.70	IISC[b]		0.01
SMMSE[c] (every 5 score)	0.98 (0.91–1.05)	0.53	Seriously ill	11.83 (1.49–93.92)	
Past fall	0.95 (0.72–1.26)	0.75	Moderate symptoms	8.59 (1.22–60.50)	
Previous fracture	1.47 (1.11–1.94)	0.008	Mild symptoms	12.21 (1.73–86.35)	
Current smoker	0.85 (0.47–1.54)	0.59	No symptoms	1.00	
History of smoking	1.10 (0.82–1.48)	0.51	25(OH)D (10 nmol/l)	1.04 (0.95–1.14)	0.40
'Bone-active' medication[d]	1.15 (0.82–1.61)	0.41	Ln(parathyroid hormone)[e]	1.06 (0.83–1.35)	0.64

[a]Age was treated as a time-dependent variable; [b]IISC—the Implicit Illness Severity Rating Scale; [c]Standardized Mini Mental State Examination; [d]'Bone-active' medication—use of any vitamin D preparation, calcium, hormone therapy or bisphosphonates; [e]Parathyroid hormone was transformed to a normal distribution by using the natural logarithm.

Table 3. Multivariate analysis of time to hip fracture with age as a time-dependent covariate

Variable	HR (95% CI)[a]	*P*
Age (year)		0.05
90–105	1.58 (0.96–2.59)	
85–89	1.48 (0.91–2.42)	
80–84	0.93 (0.52–1.64)	
65–79	1.00	
SMMSE[b] (every 5-point increase in score)	0.90 (0.82–0.99)	0.04
Previous fracture	1.42 (1.07–1.89)	0.02
Lower leg length ≥ 50.5 cm	1.45 (1.07–1.99)	0.02
Weight (kg)		0.006
27–52	1.84 (1.22–2.79)	
53–64	1.69 (1.15–2.48)	
≥65	1.00	
Total hip replacement	0.42 (0.18–0.95)	0.02
Balance (grade) by type of residence		<0.001
Nursing home		
1	0.15 (0.05–0.43)	
2–4	0.74 (0.47–1.17)	
5	1.42 (0.56–3.63)	
Hostel		
1	1.69 (0.60–4.76)	
2–4	1.20 (0.83–1.72)	
5	1.00	

[a]Calculated using robust standard error; [b]Standardized Mini Mental State Examination.

factors were cognitive impairment, a history of previous fracture since age 50, lower body weight, longer lower leg length and no previous total hip replacement (Table 3). The risk of hip fracture increased with age from 85 years onwards.

Discussion

This study confirmed that residents of aged-care facilities are at a very high risk of hip fracture with an incidence rate of 4.0% per person year. Our rate is similar to that of 3.5% reported in a cohort of 1,664 institutionalised older women with a mean age of 83.8 years in Austria [10], but much higher than the 1.1% reported in the EPIDOS study of 7,575 women aged 75 or older from the general population in France [20]. Risk factors contributing to the high incidence in this study, such as older age, lower weight, greater mature skeletal height (as reflected in the surrogate longer lower leg length), history of previous fracture and cognitive impairment, are similar to those reported in studies of community dwellers [7, 21–24]. However, our study subjects had a much higher prevalence of these risk factors than those older people in the community studies.

Our study also suggests that institutionalised older people have a number of differences in risk factors for hip fracture compared with community-dwelling people. For example, in this study we found that residents with poorer balance had an increased risk of hip fracture in an intermediate-care hostel environment but decreased risk in a high-care nursing home environment. This finding could partly be explained by differences in philosophy of nursing care between the two types of institution in Australia. Nursing home residents with very poor balance are heavily dependent on nursing staff support for their mobility, while their counterparts in hostels have assistance available for daily living activities but are unsupervised for substantial periods. Many of the nursing home residents with static balance grades of

1 were also not able to get out of a chair independently, which would reduce their exposure to falls from a standing height. The presence of dementia in hostel residents may be associated with the lack of recognition of a high risk of falling when attempting to walk. Some hostel residents who desire to remain independent may be reluctant to seek help when needed. While encouraging residents to be independent, increasing supervision for those with poorer balance or improving balance by appropriate exercise [25] could reduce the incidence of hip fracture in intermediate-care hostels.

Additionally, low BUA has been identified as an important risk factor in community studies [8, 26–28] but was not found to be independently associated with increasing risk of hip fracture in this study. The lack of ability of BUA to discriminate the risk of hip fracture may be because fall risk plays a dominant role in determining the fracture incidence in this frail older population. In a study of the impact of a fall and the breaking point of the proximal part of the femur by Lots *et al.* [29], they concluded that energy absorbed during falling and impact, rather than bone strength, may be the dominant factors in a hip fracture. In our study sample, 77% of the residents had a BUA value of <67.4 dB/MHz (data not shown). Among these residents with extremely low bone strength, a fall becomes a deciding factor for their hip fractures. The finding of our study is in keeping with the observation that the relative risk associated with a decrease in surrogate measures of skeletal fragility may decrease with advancing age. Both the Study of Osteoporotic Fractures [26] and EPIDOS study [28] have shown a declining association between BUA and hip fractures with increasing age in community-dwelling older women. In another study of 5,814 men and women aged 55 years and over in the Netherlands, De Laet *et al.* found that the decrease in bone mineral density associated with age contributed little to the exponential increase in the risk of hip fracture with age [30].

In contrast to community-dwelling studies, female residents had a similar risk of hip fracture to male residents in our study. This might be due to the fact that skeletal fragility contributed less to hip fracture incidence in this frail older population, and that falls and related risk factors will be similar in men and women in this population defined by need for residential aged care.

A few studies have specifically focused on finding risk factors for hip fracture among institutionalised older people [9, 10]. Our study findings differ in some respects from those of a prospective cohort study of 28,807 residents of nursing facilities in the USA, aged >65 years. In that study, the risk of hip fracture was significantly associated with white race, female gender, older age, cognitive impairment, previous fracture, prior falls, anxiolytic use and continence of bowel or bladder but not associated with low body weight, ambulatory or transfer ability independent. However, that study did not exclude those who were bed bound, bilateral amputees or those with total hip replacement in both legs or adjust for those who had a total hip replacement and time to hip fracture as we did in our study.

Our study has several strengths and limitations. It is one of the largest prospective cohort studies ever done in institutionalised older people. The fracture cases were collected through regular liaison with the residential care facilities and hospitals in the area. We are therefore unlikely to have missed fracture cases. Also, the inclusion of nursing home and intermediate-care hostel residents allowed examination of possible modification effects of nursing care on some functional variables. On the other hand, some participants in the study may have been using hip protectors, but the number is likely to be small. In a falls prevention study we carried out in the same geographical area during 2006–07, only 3.2% of residents living in intermediate-care hostels reported wearing hip protectors. A low participation rate of 32% among those subjects who needed their carer's consent in this study might bias the estimate of hip fracture incidence rate to be lower than the true incidence rate for this frail older population.

This study provides valuable information for identifying high-risk individuals and selecting the most appropriate and effective fracture prevention strategies for this frail older population. Some prevention programs require a few extra resources such as reducing the number of medications where possible in order to reduce the risk of falls or improved nutrition for underweight individuals. These programs should be incorporated into all residents care plans. Other prevention programs such as individualised programs for falls prevention and hip protectors are expensive and may not be cost-effective if applied to all. These programs should target residents who are most likely to benefit from the programs. The results of this study would help to rationalise the provision of these programs in this very frail population.

In summary, we have identified that risk factors for hip fracture in institutionalised older people have a number of differences to risk factors for hip fracture with community-dwelling subjects. In the very frail elderly population, the most important determinant for hip fracture is factors that are associated with risk of falls. These differences may contribute to the higher risk of hip fracture among institutionalised older people. The incidence of hip fracture in this high-risk group might be reduced by applying appropriate prevention programs according to the risk factor characteristics of the residents.

Key points

- The study confirmed that residents of aged-care facilities are at a very high risk of hip fracture.
- The study found that residents with poorer balance had an increased risk of hip fracture in an intermediate-care hostel environment but a decreased risk in a high-care nursing home environment.
- The study provides valuable information for identifying high-risk individuals and selecting the most appropriate

and effective fracture prevention strategies for this frail older population.

Acknowledgements

The authors would like to thank Jennifer Schwarz (Research Coordinator) and Jill Makaroff (Research Assistant) for their efforts in coordinating the study and collecting the data. We gratefully acknowledge the support we received from the staff members in the participating institutions. This study was supported by grants from the Australian National Health and Medical Research Council and Osteoporosis Australia.

Conflicts of interest

There are no conflicts of interest.

References

1. Katelaris AG, Cumming RG. Health status before and mortality after hip fracture. Am J Public Health 1996; 86: 557–60.
2. Marottoli RA, Berkman LF, Cooney LM Jr. Decline in physical function following hip fracture. J Am Geriatr Soc 1992; 40: 861–6.
3. Kanis JA, Johnell O, De Laet C *et al.* International variations in hip fracture probabilities: implications for risk assessment. J Bone Miner Res 2002; 17: 1237–44.
4. Singer BR, McLauchlan GJ, Robinson CM, Christie J. Epidemiology of fractures in 15,000 adults: the influence of age and gender. J Bone Joint Surg Br 1998; 80: 243–8.
5. Cumming RG, Nevitt MC, Cummings SR. Epidemiology of hip fractures. Epidemiol Rev 1997; 19: 244–57.
6. Kannus P, Parkkari J, Sievanen H *et al.* Epidemiology of hip fractures. Bone 1996; 18(1 Suppl): 57S–63S.
7. Cummings SR, Nevitt MC, Browner WS *et al.* Study of Osteoporotic Fractures Research Group. Risk factors for hip fracture in white women. N Engl J Med 1995; 332: 767–73.
8. Hans D, Durosier C, Kanis JA *et al.* Assessment of the 10-year probability of osteoporotic hip fracture combining clinical risk factors and heel bone ultrasound: the EPISEM prospective cohort of 12,958 elderly women. J Bone Miner Res 2008; 23: 1045–51.
9. Colon-Emeric CS, Biggs DP, Schenck AP, Lyles KW. Risk factors for hip fracture in skilled nursing facilities: who should be evaluated? Osteoporos Int 2003; 14: 484–9.
10. Dobnig H, Piswanger-Solkner JC, Obermayer-Pietsch B *et al.* Hip and nonvertebral fracture prediction in nursing home patients: role of bone ultrasound and bone marker measurements. J Clin Endocrinol Metab 2007; 92: 1678–86.
11. Jaatinen PT, Panula J, Aarnio P, Kivela SL. Incidence of hip fractures among the elderly in Satakunta, Finland. Scand J Surg 2007; 96: 256–60.
12. Norton R, Campbell AJ, Reid IR *et al.* Residential status and risk of hip fracture. Age Ageing 1999; 28: 135–9.
13. Sambrook PN, Cameron ID, Chen JS *et al.* Influence of fall related factors and bone strength on fracture risk in the frail elderly. Osteoporos Int 2007; 18: 603–10.
14. Zochling J, Sitoh YY, Lau TC *et al.* Quantitative ultrasound of the calcaneus and falls risk in the institutionalized elderly: sex differences and relationship to vitamin D status. Osteoporos Int 2002; 13: 882–7.
15. Holtzman J, Lurie N. Causes of increasing mortality in a nursing home population. J Am Geriatr Soc 1996; 44: 258–64.
16. Folstein MF, Folstein SE, McHugh PR. 'Mini-mental state'. A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975; 12: 189–98.
17. Lord SR, Clark RD, Webster IW. Physiological factors associated with falls in an elderly population. J Am Geriatr Soc 1991; 39: 1194–200.
18. Han TS, Lean ME. Lower leg length as an index of stature in adults. Int J Obes Relat Metab Disord 1996; 20: 21–7.
19. Chen JS, Seibel MJ, Zochling J *et al.* Calcaneal ultrasound but not bone turnover predicts fractures in vitamin D deficient frail elderly at high risk of falls. Calcif Tissue Int 2006; 79: 37–42.
20. Dargent-Molina P, Favier F, Grandjean H *et al.* Fall-related factors and risk of hip fracture: the EPIDOS prospective study. Lancet 1996; 348: 145–9.
21. Black DM, Steinbuch M, Palermo L *et al.* An assessment tool for predicting fracture risk in postmenopausal women. Osteoporos Int 2001; 12: 519–28.
22. Burger H, De Laet CE, Weel AE *et al.* Added value of bone mineral density in hip fracture risk scores. Bone 1999; 25: 369–74.
23. Dargent-Molina P, Douchin MN, Cormier C *et al.* Use of clinical risk factors in elderly women with low bone mineral density to identify women at higher risk of hip fracture: the EPIDOS prospective study. Osteoporos Int 2002; 13: 593–9.
24. McGrother CW, Donaldson MM, Clayton D *et al.* Evaluation of a hip fracture risk score for assessing elderly women: the Melton Osteoporotic Fracture (MOF) study. Osteoporos Int 2002; 13: 89–96.
25. Sherrington C, Whitney JC, Lord SR *et al.* Effective approaches to exercise in the prevention of falls—a systematic review and meta-analysis. J Am Geriatr Soc 2008; 56: 2234–43.
26. Bauer DC, Gluer CC, Cauley JA *et al.* Study of Osteoporotic Fractures Research Group. Broadband ultrasound attenuation predicts fractures strongly and independently of densitometry in older women. A prospective study. Arch Intern Med 1997; 157: 629–34.
27. Khaw KT, Reeve J, Luben R *et al.* Prediction of total and hip fracture risk in men and women by quantitative ultrasound of the calcaneus: EPIC-Norfolk prospective population study. Lancet 2004; 363: 197–202.
28. Hans D, Dargent-Molina P, Schott AM *et al.* Ultrasonographic heel measurements to predict hip fracture in elderly women: the EPIDOS prospective study. Lancet 1996; 348: 511–4.
29. Lotz JC, Hayes WC. The use of quantitative computed tomography to estimate risk of fracture of the hip from falls. J Bone Joint Surg Am 1990; 72: 689–700.
30. De Laet CE, Van Hout BA, Burger H *et al.* Bone density and risk of hip fracture in men and women: cross sectional analysis. BMJ 1997; 315: 221–5.

Received 17 October 2008; accepted in revised form 12 March 2009