Osteoporos Int (2004) 15: 639–644
DOI 10.1007/s00198-004-1587-4

ORIGINAL ARTICLE

Prevalence and risk factors of distal radius and calcaneus bone mineral density in Korean population

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Received: 5 May 2003 / Accepted: 9 January 2004 / Published online: 24 March 2004

Abstract To estimate the prevalence and the related risk factors of low bone mineral density of the calcaneus and the distal radius, a community-based study was conducted in three rural areas of Korea. A total of 1420 women and 732 men aged 40 years and older participated in this study. Information on sociodemographic characteristics and the potential risk factors for osteoporosis were collected by an interviewer-administered standardized questionnaire. Bone mineral density (BMD) of the calcaneus and the distal radius were measured by dual-energy X-ray absorptiometry (DXA). Three hundred and seventeen women and 183 men aged 20–29 years who participated in a regular health check-up were used as a reference population. Osteoporosis was defined using WHO criteria. Odds ratios of the risk factors of osteoporosis were calculated by the unconditional logistic regression model. The standardized prevalence of osteoporosis of the calcaneus was 8.4% for males and 27.3% for females using the Korean population of year 2000 as a standard population. The standardized prevalence of osteoporosis of the distal radius was 4.2% for males and 18.8% for females. Older age and lower body mass index (BMI) were related with low BMD in both the calcaneus and distal radius in males and females. The duration after menopause and the number of live births were an independent risk factor for osteoporosis of the calcaneus (OR = 1.1, 95% CI = 1.00–1.11; the duration after menopause; OR = 2.0, 95% CI = 1.20–3.35, the number of live birth) and a familial history of non-traumatic fractures or osteoporosis among the first-degree relatives was significantly related to a increased risk of osteoporosis of the distal radius in females (OR = 2.9, 95% CI = 1.36–6.31).

Keywords Bone mineral density · Korean · Osteoporosis · Prevalence · Risk factors

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Introduction

Osteoporosis is defined as a systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of the bone tissue, leading to enhanced bone fragility and a consequent increased fracture risk [1]. Low bone mineral density (BMD) is a good predictor of the development of non-pathologic fractures [2]. According to the WHO criteria, osteoporosis is defined as a BMD

2.5 SD or more below the peak bone mass of a young, healthy sex- and race-matched reference population [1], and osteopenia is defined as a BMD between 1.0 and 2.5 SD below the peak bone mass. The expected life span of the Korean population is increasing as in most western countries. In 2000, the proportion of elders, defined as 65 years old or more, in the Korean population was 7.4% and in 2020 it is expected to reach 15.1% [3]. This trend indicates that osteoporosis related fractures may become a major health problem in elderly people in Korea.

The prevalence of osteoporosis determined by previous studies conducted mainly among Caucasians ranges from 4.1% to 38.0% [4,5,6,7,8,9,10,11,12,13]. These discrepancies might be due to several factors, including subjects studied (e.g. ethnicity, age), the reference populations used, measuring sites (lumbar spine, femoral neck, calcaneus, distal radius) and the measuring method [dual-energy X-ray absorptiometry (DXA), single-energy X-ray absorptiometry, quantitative ultrasonography].

Risk factors of osteoporosis such as age, menopause, family history of fracture and obesity have shown consistent results in many studies [14,15,16,17], whereas other factors (e.g. deficiency of calcium and vitamin D, decreased physical activity, cigarette smoking, long-term use of some drugs, such as corticosteroids, GnRH antagonists, thyroxine, and some anticancer drugs remain inconclusive. Although DXA is an optimum method to estimate bone mass in a clinical setting [18], relatively few studies have been performed upon measuring the BMD of the calcaneus or distal radius using this technique. Moreover, most of the studies have been conducted in Caucasians and no large-scale community-based study using DXA, including both males and females and an analysis of risk factors, has been conducted in Korea. Thus, we conducted the community-based study to estimate the prevalence of low bone mineral density using DXA and to identify risk factors with respect to low bone mineral density in the Korean population.

Materials and methods

Subjects

Three rural areas of South Korea were selected for this study. All residents aged 40 years and older were invited to participate. One area, Sinbuk-up, Chunchon City, located in the northern part of South Korea, consisted of 4181 (1950 males and 2231 females) residents aged 40 years and older. Of these, 660 residents (233 males and 427 females) participated (participation rate 16%). Another area, Kangwha-up, located in the western part of Korea, had 3448 residents aged 40 years and older. Of these, 943 residents (273 males and 670 females) participated (participation rate 27%). The third area included three counties in Chungju City, located in the center of Korea, consisted of 8054 residents aged 40 years and older. Of these, 713 residents (282 males and 431 females) participated (participation rate 9%). Finally, a total of 788 males and 1528 females aged 40 years and older were recruited. Of these, 732 males and 1420 females with both BMD measurements remained in this study. Informed consent was obtained from all participants.

Questionnaire and examination

A standardized questionnaire was used to evaluate the risk factors for osteoporosis, including sociodemographic factors, past and current medical history, medication history, family history on osteoporosis of non-traumatic fractures, smoking and drinking habits, and physical activity. For females, reproduction history including age at menarche, age at menopause, reason for menopause, numbers of full-term pregnancies and live births, duration of breastfeeding, history of abortions (both spontaneous and artificial), and use of oral contraceptives and hormone replacement therapy (HRT) were obtained. All interviews were conducted by trained interviewers, and participants' heights and weights were recorded.

Measurement of bone mineral density

BMD of the right calcaneus and distal radius were measured by DXA using Lunar PIXI instruments. Calibration was done daily. A total of 317 healthy Korean females and 183 healthy Korean males aged 20–29 who participated in a regular health check-up were used as the reference population. The mean and the standard deviation (SD) of calcaneus BMD in young males and females was 0.613 ± 0.100 and 0.494 ± 0.076, respectively. The mean and SD of distal radius in males and females was 0.550 ± 0.064 and 0.465 ± 0.061, respectively (Table 1). As the WHO *T*-score criteria, subjects were categorized as: osteopenia, BMD values between 1 and 2.5 SD, osteoporosis, BMD values ≥2.5 SD below the mean of a young Korean reference population (Table 1).

Analysis

To estimate the prevalence of osteoporosis, the age- and sex-specific prevalences of osteoporosis were calcuated. The age-standardized prevalence was calculated using distribution of Korean population for the year 2000 [3] and the World Standard Population as standard populations [19]. A logistic regression model was used to estimate the odds ratios of the risk factors for osteoporosis. Persons categorized as having normal BMD were regarded as controls and persons with a BMD in the osteoporotic range were regarded as cases. All analysis was performed stratified by sex and the BMD measuring sites.

Results

The demographic characteristics and distributions of the selected risk factors of the study population are listed in Table 2.

Tables 3 and 4 show the age- and sex-specific, and the standardized prevalences of osteoporosis of the calcaneus and of the distal radius. The standardized preva-

Table 1 Mean BMD values with standard deviations of reference population aged 20–29 years old healthy Korean (unit: g/cm^2)

Site	Mean	SD	Cutoff values of BMD	
			Osteopenia	Osteoporosis
Male (n=183)				
Calcaneus	0.613	0.100	0.367–0.515	< 0.367
Distal radius	0.550	0.064	0.394–0.488	< 0.394
Female (n=317)				
Calcaneus	0.494	0.076	0.304–0.418	< 0.418
Distal radius	0.465	0.061	0.318–0.406	< 0.318

Table 2 General characteristics of study populations

	Male		Female	
	n	(%)	*n*	(%)
Age				
40–49	101	(13.8)	242	(17.0)
50–59	135	(18.4)	375	(26.4)
60–69	299	(40.9)	491	(34.6)
70–79	162	(22.1)	258	(18.2)
≥80	35	(4.8)	54	(3.8)
Height (mean ± SD, cm)	163.5 ± 7.1		152.4 ± 6.4	
Weight (mean ± SD, kg)	64.2 ± 10.2		56.8 ± 9.3	
BMI (mean ± SD, kg/m^2)	24.0 ± 3.2		24.4 ± 3.5	
Education				
Elementary school	482	(66.3)	1193	(84.1)
Middle school	130	(17.9)	140	(9.9)
High school/college	115	(15.8)	89	(6.1)
Smoking (mean ± SD, pack-year)	17.4 ± 21.4		0.8 ± 5.3	
Alcohol consumption				
Non-drinker	172	(36.9)	945	(78.8)
≤ 1/week	95	(20.4)	212	(17.7)
≥2/week	199	(42.7)	42	(3.5)
Familial history of osteoporosis or fracture				
No	504	(92.3)	1013	(90.5)
Yes	42	(7.7)	107	(9.6)
Duration after menopause	–	–	15.6 ± 10.7	
Age of first full-term delivery				
≤ 20	–	–	290	(21.4)
21–24	–	–	612	(45.1)
≥25 or nulliparous	–	–	456	(33.6)
Number of births				
< 4	–	–	623	(44.7)
≥4	–	–	771	(55.3)
Hormone replacement therapy				
No	–	–	1276	(89.9)
Yes	–	–	144	(10.1)
Total	732	(100.0)	1420	(100.0)

Table 3 Standard prevalence of low bone mineral density of the calcaneus

	Male						Female					
	Normal		Osteopenia		Osteoporosis		Normal		Osteopenia		Osteoporosis	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Age group												
40–49	65	(64.4)	33	(32.7)	3	(3.0)	175	(72.3)	64	(26.5)	3	(1.2)
50–59	55	(40.7)	73	(54.1)	7	(5.2)	121	(32.3)	183	(48.8)	71	(18.9)
60–69	86	(28.8)	164	(54.9)	49	(16.4)	45	(9.2)	203	(41.3)	243	(49.5)
70–79	35	(21.6)	83	(51.2)	44	(27.2)	7	(2.7)	51	(19.8)	200	(77.5)
≥80	4	(11.4)	17	(48.6)	14	(40.0)	0	(0.0)	6	(11.1)	48	(88.9)
Korean population[a]	–	–	–	44.3	–	8.4	–	–	–	33.7	–	27.3
World population[b]	–	–	–	45.8	–	10.0	–	–	–	34.9	–	26.6

[a]Standardized prevalence of adults over 40 years per 100 persons adjusted for the distribution of the Korean population, 2000
[b]Standardized prevalence of adults over 40 years per 100 persons adjusted for the distribution of the world standard population

lence of the osteoporosis of the calcaneus of 40 years old or more was 8.4% for males and 27.3% for females, using the year 2000 Korean population as the standard population. The standardized prevalence of the osteoporosis of distal radius was 4.2% and 18.8% for males and females, respectively.

Tables 5 and 6 display the odds ratios of selected risk factors for osteoporosis. The most consistent results observed across both sexes and measuring sites were that the risk of osteoporosis increased as age increased, and decreased as the body mass index increased. There was a significant association between educational levels and calcaneal BMD in both males and females; individuals educated at or over high school level had a decreased risk of osteoporosis compared with individuals educated at elementary school level (OR = 0.4, 95% CI = 0.18–1.00 in males; OR = 0.2, 95% CI = 0.06–0.82 in females). The duration after menopause and the number of live births were independent risk factors of calcaneus in females (OR = 1.1, 95% CI = 1.00–1.11, duration after

Table 4 Standard prevalence of low bone mineral density of the distal radius

	Male						Female					
	Normal		Osteopenia		Osteoporosis		Normal		Osteopenia		Osteoporosis	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Age group												
40–49	96	(95.1)	5	(5.0)	0	(0.0)	232	(95.9)	10	(4.1)	0	(0.0)
50–59	113	(83.7)	19	(14.1)	3	(2.2)	227	(60.5)	127	(33.9)	21	(5.6)
60–69	178	(59.5)	97	(32.4)	24	(8.0)	103	(21.0)	237	(48.3)	151	(30.8)
70–79	67	(41.4)	63	(38.9)	32	(19.8)	18	(7.0)	62	(24.0)	178	(69.0)
≥80	7	(20.0)	13	(37.1)	15	(42.9)	0	(0.0)	6	(11.1)	48	(88.9)
Korean population[a]	–	–	–	15.5	–	4.2	–	–	–	23.0	–	18.8
World population[b]	–	–	–	17.7	–	5.6	–	–	–	24.2	–	17.6

[a]Standardized prevalence of adults over 40 years per 100 persons adjusted for the distribution of the Korean population, 2000
[b]Standardized prevalence of adults over 40 years per 100 persons adjusted for the distribution of the world standard population

Table 5 Risk factors of osteoporosis for female

	Calcaneus		Distal radius	
	Cases/controls	aOR[a](95% CI)	Cases/controls	aOR[a](95% CI)
Age (years)	–	1.3 (1.29–1.40)	–	1.3 (1.29–1.39)
BMI (kg/m^2)	–	0.7 (0.65–0.76)	–	0.8 (0.78–0.90)
Years since menopause	–	1.1 (1.00–1.11)	–	1.0 (0.97–1.05)
Education				
Elementary school	535/215	1.0	382/413	1.0
Middle school	21/78	0.6 (0.29–1.34)	10/103	0.9 (0.35–2.18)
High school/college	9/54	0.2 (0.06–0.82)	6/63	0.6 (0.12–3.09)
Smoking (pack-year)	–	0.9 (0.89–0.96)	–	1.0 (0.94–1.00)
Alcohol consumption				
Non-drinker	417/195	1.0	287/348	1.0
≤ 1/week	57/80	0.6 (0.31–1.32)	41/121	1.1 (0.54–2.16)
≥2/week	11/13	0.6 (0.13–2.71)	12/20	1.9 (0.52–6.83)
Family history of osteoporosis or fracture				
No	430/235	1.0	305/388	1.0
Yes	36/21	2.0 (0.84–4.68)	28/39	2.9 (1.36–6.31)
Age at first full-term delivery				
≤ 20	159/37	1.0	129/89	1.0
21–24	244/147	0.9 (0.43–1.74)	167/233	1.8 (0.97–3.18)
≥25 or nulliparous	134/150	0.8 (0.38–1.64)	81/237	1.5 (0.78–2.85)
Number of births				
< 4	147/270	1.0	94/392	1.0
≥4	408/75	2.0 (1.20–3.35)	297/183	1.1 (0.70–1.86)
Hormone replacement therapy				
No	534/299	1.0	380/500	1.0
Yes	31/49	0.8 (0.42–1.56)	18/80	0.9 (0.45–1.95)

[a]Adjusted for age and BMI

Table 6 Risk factors of osteoporosis for males

	Calcaneus		Distal Radius	
	Cases/controls	aOR[a](95% CI)	Cases/controls	aOR[a](95% CI)
Age (years)	–	1.1 (1.07–1.13)	–	1.2 (1.12–1.20)
BMI (kg/m^2)	–	0.7 (0.60–0.75)	–	0.9 (0.79–0.96)
Education				
Elementary school	96/126	1.0	63/269	1.0
Middle school	10/55	0.4 (0.18–1.11)	7/101	0.9 (0.36–2.33)
High school/college	11/61	0.4 (0.18–1.00)	4/88	0.4 (0.13–1.25)
Smoking (pack-year)	–	1.0 (0.99–1.02)	–	1.0 (0.98–1.01)
Alcohol consumption				
Non-drinker	39/44	1.0	26/97	1.0
≤ 1/week	13/30	0.8 (0.27–2.24)	7/66	0.8 (0.29–2.18)
≥2/week	23/74	0.8 (0.32–1.78)	16/136	1.4 (0.59–3.08)
Familial history of osteoporosis or fracture				
No	91/163	1.0	50/314	1.0
Yes	6/16	0.6 (0.15–2.09)	4/28	1.2 (0.33–4.50)

[a]Adjusted for age and BMI

menopause; OR = 2.0, 95% CI = 1.20–3.35, number of live births). A positive family history of non-traumatic fractures or osteoporosis increased the risk of osteoporosis of the distal radius in females (OR = 2.9, 95% CI = 1.36–6.31).

Discussion

In the present study, the prevalence of osteoporosis of the calcaneus and the distal radius was estimated in three Korean rural communities. The prevalences of osteoporosis were 8.4% for males and 27.3% for females in the calcaneus and 4.2% and 18.8% for males and females in the distal radius after standardizing for age distribution of the Korean population.

Comparing the prevalences of osteoporosis reported in different studies is not easy due to the different measuring sites used, the age range of the study participants, and of the reference populations. Table 7 summarizes the results of previous studies, and shows that the prevalence of osteoporosis varies significantly between countries. Few studies have presented adjusted prevalence rates using either age distributions of their own countries or those of the World Standard Population.

A Chinese study on the BMD of the calcaneus reported age specific prevalences for osteoporosis in males and females [11]. These prevalences were lower than our results for both sexes (Table 7); in our study, age-standardized prevalences of osteoporosis of subjects aged 60 years and older were 62.8% for females and 20.7% for males. In a sample of a Bulgarian female referral population, the authors reported that osteoporosis of the distal radius was found in 20% of all females aged 50 years and older [10]. The age-specific prevalence of the Bulgarian study was lower than that obtained in the present study for all age groups. In a Japanese study, Iki et al. (2001) estimated the prevalence of osteoporosis of the distal radius in the Japanese population at age 50–79 years as 36.6% [5], which is similar to our result; in this study, age-standardized prevalence of osteoporosis of the women aged 50–79 years and older was 41.4%.

The reason why our subjects showed a relatively higher prevalence might be due to the differences in the reference values, the BMD measuring devices, and/or the criteria used to define osteoporosis. The higher prevalence observed in this study, however, is more likely due to the characteristics of the subjects recruited; our study subjects were older, had lower BMI (overall mean BMI: 24.3 kg/m^2), and were less educated (more than 90% of the subjects under middle school education) than the subjects reported previously.

Although peripheral BMD measurements are not usually used in regular clinical practice, they could be applied to a large scale community-based survey because of their easy accessibilities and fair predictability of fracture occurrence. Stone et al. (2003) reported that peripheral BMD measurements (e.g. calcaneus, distal radius) had almost equivalent predictability to central BMD measurement for risk of fracture of various anatomical sites [19]. Sweeney et al. (2002) also reported that the calcaneus BMD showed high sensitivity and specificity in predicting the low BMD of femoral neck and lumbar spine [20].

In the risk factor analysis, an older age and a lower body mass index were found to be consistent risk factors for males and females as shown in previous many reports. BMI has been found to be inversely associated with fracture risk and bone mass in many studies, but the mechanism is unclear. Higher impact during weight-bearing activities, nutritional conditions and hormonal effects are possible mechanisms for the protective effect of a higher BMI [17]. A positive family history for non-traumatic fractures or osteoporosis showed increased risk only in female distal radius. Increased risks of osteoporosis in those with a family history of osteoporosis or non-traumatic fracture are suggested to indicate a genetic contribution to the development of osteoporosis.

There is no association between BMD and alcohol drinking. Moderate alcohol consumption has been related to a higher BMI by some studies [21,22], but others have failed to show this association [23,24]. Alcohol might affect bone density by increasing levels of endogenous estrogen [22]. A recent meta-analysis of cigarette smoking and bone mineral density showed that bone loss was greater only in postmenopausal women who smoked, not in premenopausal women [25]. However, Grainge et al. (1998) reported that BMD was significantly reduced in both pre- and postmenopausal

Table 7 Prevalence of osteoporosis from previous studies. *DXA* dual energy X-ray absorptiometry, *SXA* single-energy X-ray absorptiometry, *QUS* quantitative ultrasound

Authors	Country	Number of participants (age)	Reference population	BMD measuring methods	Sites	Prevalence (%)
Females						
Xu et al. [11]	China	2100 (60 and above)	1323 aged 20–49	SXA	Calcaneus	32.1
Kim et al. [12]	Korea	552 (50 and above)	238 healthy women aged 20–29	QUS	Calcaneus	11.8
Iki et al. [5]	Japan	1522 (50–79)	1403 premenopausal women	DXA	Distal radius	36.3
Maalouf et al. [13]	Lebanon	565 (50–79)	Lebanon reference data	DXA	Distal radius	13.0
Boyanov et al. [10]	Bulgaria	6221 (50 and above)	165 aged under 44	SXA	Distal radius	20.5
Males						
Xu et al. [13]	China	2379 (60 and above)	620 men aged 20–49	SXA	Calcaneus	6.6

women who smoked at all five BMD measuring sites examined [24]. Although only a small percentage of females smoke (6%), this studies showed no association between smoking and osteoporosis in both males and females.

The limitations of our study include the following. The participation rates were low (9–27%) and the study population contained more persons in the 60–70 age group than the eligible population. In addition, older subjects are more likely to be less educated and vulnerable to the risk factors of low BMD. Inaccurate recall and BMD measurement errors are also likely to have occurred. However, such a misclassification bias would result in an underestimation of the true association.

Further studies combining risk factors and genetic predisposing factors would give informative insights into the pathogenesis and the preventive strategies of osteoporosis.

Acknowledgements This study was supported by a grant from the Korean Ministry of Health and Welfare (01-PJ1-PG1-01CH08-0001).

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