J Bone Miner Metab (2016) 34:347–353
DOI 10.1007/s00774-015-0676-0

ORIGINAL ARTICLE

Different reference BMDs affect the prevalence of osteoporosis

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Received: 28 January 2015 / Accepted: 19 April 2015 / Published online: 10 June 2015
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Abstract The T score represents the degree of deviation from the peak bone mineral density (BMD) (reference standard) in a population. Little has been investigated concerning the age at which the BMD reaches the peak value and how we should define the reference standard BMD in terms of age ranges. BMDs of 9,800 participants were analyzed from the Korean National Health and Nutrition Examination Survey database. Five reference standards were defined: (1) the reference standard of Japanese young adults provided by the dual-energy X-ray absorptiometry machine manufacturer, (2) peak BMD of the Korean population evaluated by statistical analysis (second-order polynomial regression models), (3) BMD of subjects aged 20–29 years, (4) BMD of subjects aged 20–39 years, and (5) BMD of subjects aged 30–39 years. T-scores from the five reference standards were calculated, and the prevalence of osteoporosis was evaluated and compared for males and females separately. The peak BMD in the polynomial regression model was achieved at 26 years in males and 36 years in females in the total hip, at 20 years in males and 27 years in females in the femoral neck, and at 20 years in males and 30 years in females in the lumbar spine. The prevalence of osteoporosis over the age of 50 years showed significant variation of up to two fold depending on the reference standards adopted. The age at which peak BMD was achieved was variable according to the gender and body sites. A consistent definition of peak BMD needs to be established in terms of age ranges because this could affect the prevalence of osteoporosis and healthcare policies.

Keywords Bone mineral demsity · Reference standard · T-score · Osteoporosis · DXA

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Introduction

Osteoporosis and related fractures pose a major health and economic burden worldwide [1, 2]. The incidence of disability following an osteoporotic hip fracture exceeds that of stroke, heart disease, and cancer and is associated with a significant loss of independence [3]. Osteoporosis-related disability has increased with the lengthening life expectancy. The increasing rates of morbidity and mortality associated with osteoporosis add an enormous cost to the economy [4, 5]. Annual direct costs of osteoporotic fractures are increasing [5].

Bone mineral density (BMD) is recognized as one of the main predictive factors of osteoporosis and osteoporotic fractures [6, 7]. A wide variety of techniques is available to

measure BMD [6, 8]. Among them, the most widely used technique is based on dual-energy X-ray absorptiometry (DXA) [9]. Although DXA has technical limitations, measurement of the BMD of the spine and hip using DXA is the gold standard for the diagnosis of osteoporosis [10].

Unlike common clinical measurements such as blood pressure or hemoglobin, the accepted normal values for BMD have not been established [6, 11]. Accordingly, the T-score has been suggested as a way of simplifying the interpretation of BMD. The T-score is defined as the difference between the measured BMD and the average BMD of young healthy adults divided by the standard deviation (SD), where the BMD of young healthy adults is considered to represent the peak BMD of the population and to provide the reference standard for calculating T-scores. It provides a statistical value for the measured BMD, which can be categorized into normal, osteopenia, and osteoporosis [6].

However, the optimal age range of young healthy adults representing the peak BMD of a population has not been established, and previous studies have used different age groups to calculate the peak BMD as a reference standard [12–17]. Furthermore, some countries continue to use the reference standard of other countries or ethnic groups, although recent studies have postulated that osteoporosis should be diagnosed based on the peak BMD of the subject's ethnic population [10]. It is hypothesized that the prevalence of osteoporosis varies according to the reference standard for peak BMD of the young healthy adults applied, i.e., it depends on how we define young healthy adults in terms of age range.

Therefore, the aim of this study was to determine the effect of using several different reference standards for peak BMD on the prevalence of osteoporosis in a noninstitutionalized Korean population using the fifth Korean National Health and Nutrition Examination Survey (KNHANES V) database.

Materials and methods

Study population

We recruited participants from the first (2010) and second (2011) year of the KNHANES V database. KNHANES is a national program designed to assess the health and nutritional status of adults and children in Korea. It has been performed periodically since 1998, and in 2007, the survey became a continuous, annual survey program performed by the Korea Centers for Disease Control and Prevention. It provides a variety of health measurements to the World Health Organization and the Organization for Economic Cooperation and Development.

This survey used a complex, multistage probability sample design. The sample represents the total noninstitutionalized civilian population of Korea. The survey was composed of a health examination survey, a health interview survey, and a nutrition survey. This study was conducted using data from the 2010 and 2011 KNHANES V database.

Each year, over 10,000 people aged >1 year from 3,840 families in 192 districts of Korea participate in the KNHANES. The BMD of the lumbar spine and left femur was measured in all survey participants. In participants with a history of a previous operation, fracture or deformity of the left femur, an examination was performed in right femur. Exclusion criteria were (1) subjects aged <10 years, (2) pregnant women and subjects with the possibility of pregnancy, (3) subjects with severe scoliosis or disability that prohibited them from lying down on the DXA scan table, (4) subjects whose weight exceeded the limit of the DXA scan table (159 kg), and (5) subjects who had undergone a contrast examination within 7 days or a nuclear medicine examination within 3 days. Ultimately, 9,800 participants (4,357 males and 5,443 females) aged 10–97 years were included in the analysis. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention. Written informed consent was obtained from all subjects.

Body size measurement and bone mineral density examination

A structured questionnaire including information on demographics, education, smoking, alcohol intake, exercise, and medical history was administered by trained interviewers. Height and weight were measured by a nurse who had received special training in the use of the SECA 225 height meter (Vogel & Halke, Hamburg, Germany) and the GL-6000-20 weight meter (G-tech, Seoul, Korea). The body mass index (BMI) was obtained by dividing the weight (kg) by the square of the height (m^2). Height was measured within 0.1 cm, and weight was measured to the nearest 0.01 kg in patients wearing only underwear and without shoes.

BMDs were measured by dual-energy X-ray absorptiometry (DISCOVERY-W fan-beam densitometer; Hologic, Inc., Waltham, MA, USA). Total femur, femoral neck, and lumbar spine BMDs were measured. L1–L4 values were chosen for the lumbar spine BMD analysis. We analyzed the results of the DXA using industry standard techniques at the Korean Society of Osteoporosis and Hologic Discovery software (version 13.1; Hologic, Inc., Waltham, MA, USA) in its default configuration. Education and

quality control for the examiners were provided. For precision assessment, the coefficient of variation in all examiners was assessed by obtaining three repeat measurements in 30 subjects. The coefficient of variation ranged from 0.71 to 1.18 % for the total femur, 1.2 to 2.14 % for the femoral neck, and 0.73 to 1.07 % for the lumbar spine. All subscales were checked within the permissible range (total femur <1.9 %, femoral neck <2.5 %, and lumbar spine <1.9 %). Daily quality control was performed using a spine phantom that was provided by the manufacturer (Hologic, Inc., Waltham, USA). Every day, the densitometer function, quality of radiation, and coefficient of variation were checked.

Reference standards of BMD, T-score calculation, and diagnosis of osteoporosis

The measured BMDs were converted into T-scores using several reference standards, which were peak BMDs of young healthy subjects, but the ages of the young healthy subjects varied according to those used in previous studies. Five reference standards were defined in this study: (1) reference standards of Japanese young subjects provided by the DXA machine manufacturer, (2) peak BMD of the Korean population evaluated by statistical analysis (second-order polynomial regression models), (3) average BMD of subjects aged 20–29 years, (4) average BMD of subjects aged 20–39 years, and (5) average BMD of subjects aged 30–39 years. Data analysis was performed separately for males and females.

Osteoporosis, osteopenia, and normal status were diagnosed by a T-score of ≤–2.5, >–2.5 to <–1.0, and ≥–1.0, respectively [18]. In addition, according to the recommendation of the International Society for Clinical Densitometry, osteoporosis was diagnosed based on the lowest T-score among the three sites (lumbar spine, total hip, femoral neck) [18]. Furthermore, if the T-score of any of the three sites was ≤–2.5, the status was diagnosed as overall osteoporosis [18].

Statistical analysis

Descriptive statistics were performed for all data sets including average and standard deviations. The Kolmogorov-Smirnov test was conducted for data normality. A polynomial regression model was used to identify the age showing the peak BMD. We applied the functional relationship between BMD and age to construct a reference range. The second-order polynomial regression models were fitted to the total hip, femoral neck, and lumbar spine. BMD as a function of age was as follows: $\mathrm{BMD} = \beta_0 + \beta_1(\mathrm{age}) + \beta_2(\mathrm{age})^2$, where β_0 is the intercept and β_1, β_2 are parameters estimated from the observed data.

Table 1 Baseline characteristics of the study cohort

Characteristics	Males ($n = 4357$)	Females ($n = 5334$)
Age (years)	43.9 (19.9)	45.5 (19.0)
Weight (kg)	67.6 (12.6)	56.5 (9.8)
Height (cm)	168.8 (8.9)	156.6 (6.6)
Body mass index (kg/m^2)	23.5 (3.4)	23.0 (3.7)
Total femur BMD (g/cm^2)	0.935 (0.133)	0.826 (0.126)
Femur neck BMD (g/cm^2)	0.795 (0.134)	0.695 (0.125)
Trochanter BMD (g/cm^2)	0.677 (0.097)	0.609 (0.096)
Intertrochanter BMD (g/cm^2)	1.118 (0.169)	0.994 (0.158)
Ward BMD (g/cm^2)	0.618 (0.165)	0.563 (0.169)
Lumbar BMD (g/cm^2)	0.930 (0.163)	0.885 (0.159)

Data are presented as mean (SD)

Based on the parameters in the second-order polynomial regression models, we determined the means of the peak BMD and the standard deviation for the total hip, femoral neck, and lumbar spine BMD. Peak BMD was calculated as the average of the BMDs of the subjects between 5 years before and 5 years after the age of peak BMD. Statistical analysis was conducted using SPSS version 20.0 for Windows (IBM Co., Armonk, NY, USA) and R software environment, version 3.1.1 (R Foundation for Statistical Computing, Vienna, Austria; ISBN 3-900051-07-0, http://www.r-project.org) using the statistics with the psych package.

Result

Basic characteristics and BMDs of the subjects are presented in Table 1. In total, 9800 subjects were included in the data analysis. There were 4357 males with a mean age of 43.9 years (SD 19.9; range 10–91) and 5443 females with a mean age of 45.5 years (SD 19.0; range 10–97).

Age of peak BMD and reference standards of peak BMDs

The age at which the peak BMD was achieved in the total hip in the polynomial regression model was 26 years in males and 36 years in females; in the femoral neck, it was 20 years in males and 27 years in females; in the lumbar spine, it was 20 years in males and 30 years in females. Therefore, the age at which peak BMD was achieved in males was 7–10 years earlier than in females at all three sites (Figs. 1, 2).

In the comparison of the candidate reference standard BMDs for calculating T-scores, the average BMD of the total hip between 20 and 29 years, that of femoral neck from the polynomial regression analysis, and that of the

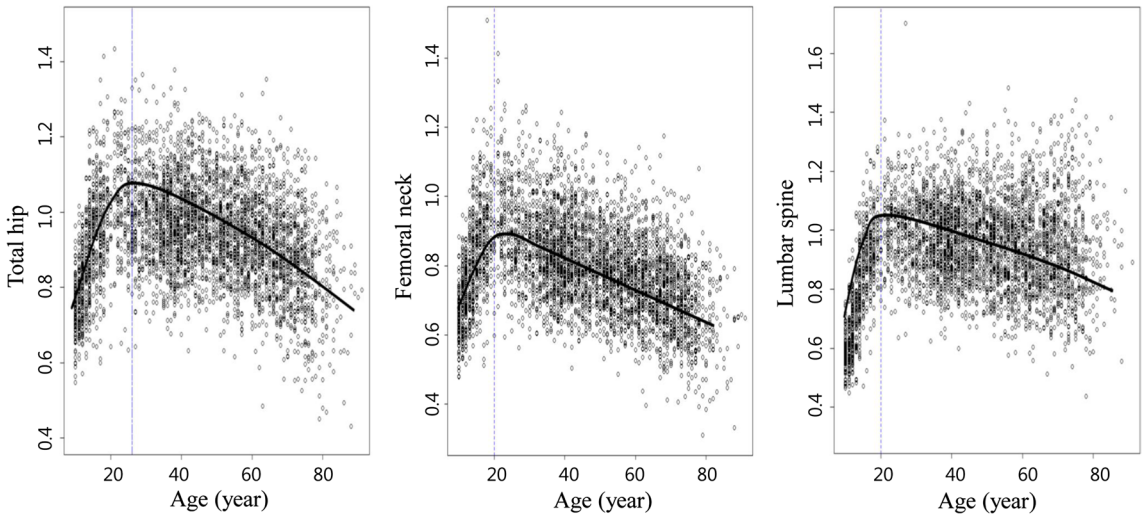

Fig. 1 Relationship between age and bone density at the total hip, femoral neck, and lumbar spine for males

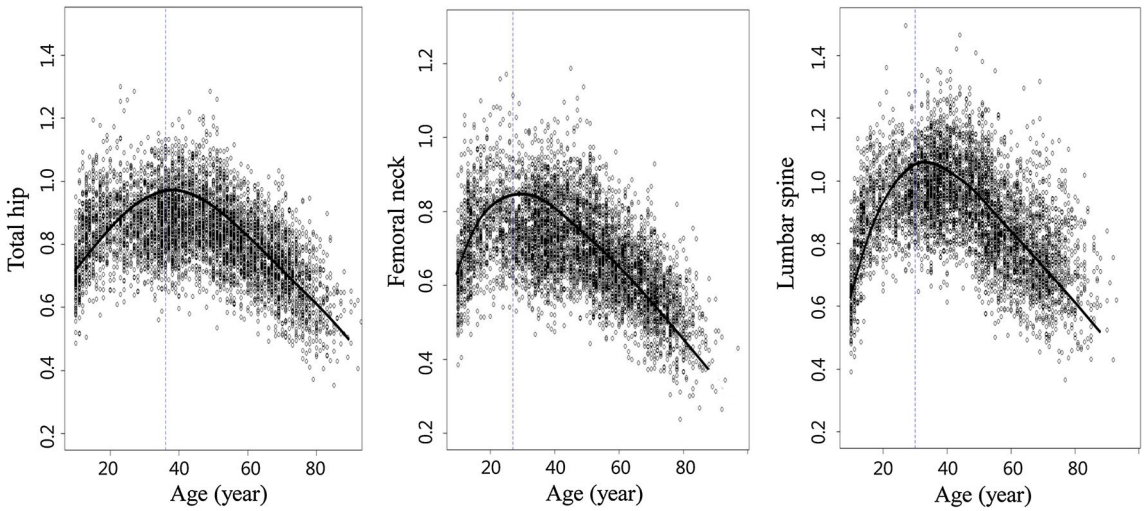

Fig. 2 Relationship between age and bone density at the total hip, femoral neck, and lumbar spine for females

Table 2 Reference values of various reference standard

References	Males			Females		
	Total hip	Femoral neck	Lumbar spine	Total hip	Femoral neck	Lumbar spine
Japan reference	0.940 ± 0.137	0.846 ± 0.124	1.024 ± 0.120	0.851 ± 0.115	0.803 ± 0.107	1.006 ± 0.114
Korean reference polynomial	0.999 ± 0.124	0.929 ± 0.142	0.983 ± 0.126	0.882 ± 0.104	0.764 ± 0.102	0.973 ± 0.109
Korean reference 20−29	1.010 ± 0.129	0.906 ± 0.134	1.003 ± 0.128	0.876 ± 0.104	0.770 ± 0.106	0.958 ± 0.111
Korean reference 20−39	0.988 ± 0.127	0.865 ± 0.128	0.986 ± 0.125	0.877 ± 0.103	0.758 ± 0.102	0.977 ± 0.114
Korean reference 30−39	0.976 ± 0.115	0.844 ± 0.119	0.977 ± 0.123	0.878 ± 0.103	0.751 ± 0.100	0.987 ± 0.114

Data are presented as mean ± SD

lumbar spine from the Japanese reference standard showed the highest values in male subjects. The average BMD of the total hip from the polynomial regression analysis and those of the femoral neck and lumbar spine from the Japanese reference standard showed the highest value in female subjects (Table 2).

Table 3 Prevalence of osteoporosis of Korean males and females aged over 50 using different references

Region	References used	Osteoporosis			Osteopenia			Normal		
		Males (%)	Females (%)	Total (%)	Males (%)	Females (%)	Total (%)	Males (%)	Females (%)	Total (%)
Total hip	Japan[a]	1.1	5.8	3.7	18.1	36.1	28.1	80.8	58.1	68.2
	Polynomial[b]	4.0	12.6	8.8	35.3	43.5	39.8	60.7	43.8	51.4
	20−29	4.0	11.0	8.0	37.0	41.0	39.3	25.3	27.3	52.7
	20−39	3.3	11.5	8.0	30.8	40.9	36.6	65.9	47.6	55.4
	30−39	4.0	11.6	8.3	30.1	41.2	36.4	65.9	47.3	55.2
Femoral neck	Japan	3.6	21.7	13.6	40.7	55.7	49.0	55.7	22.6	37.4
	Polynomial	7.1	15.2	11.6	58.8	51.8	54.9	34.1	33.0	33.5
	20−29	6.6	13.6	10.6	54.7	51.2	52.7	38.7	35.2	36.7
	20−39	3.9	13.1	9.1	44.9	48.7	47.1	51.3	38.2	43.8
	30−39	3.9	12.6	8.8	41.2	47.7	44.9	54.9	39.8	46.3
L-spine	Japan	6.7	29.8	19.3	36.0	45.4	41.1	57.4	24.7	39.6
	Polynomial	2.7	25.3	15.0	28.4	43.8	36.8	68.9	30.9	48.2
	20−29	3.7	19.3	12.4	31.9	42.1	37.6	64.5	38.7	49.9
	20−39	3.1	21.7	13.6	28.9	43.9	37.3	68.0	34.5	49.1
	30−39	2.8	24.2	14.9	27.8	43.3	36.5	69.4	32.5	48.6

[a] Japan means Japanese reference

[b] Polynomial means the reference age between 5 years before and 5 years after the age of peak BMD measured by polynomial regression model

Prevalence of osteoporosis according to various reference standards

T-scores from the five reference standards (peak BMD and SD) were calculated, and the prevalence of osteoporosis and osteopenia at age ≥50 years was evaluated and compared for males and females separately. The prevalence of osteoporosis varied depending on the reference standards applied. The prevalence at the femoral neck ranged from 3.6 to 7.1 % in males and from 12.6 to 21.7 % in females. The prevalence at the lumbar spine ranged from 2.8 to 6.7 % in males and from 19.3 to 29.8 % in females (Table 3).

Discussion

This study investigated the five possible Korean reference standards of BMD for calculating T-scores, which is used to determine the prevalence of osteoporosis in the population [11, 18]. Although clinicians agree that the T-score is calculated based on the peak BMD of young healthy adults in the population, the age at which males and females show the peak BMD at various body sites has not been determined [5, 10, 13, 14, 16, 17]. Furthermore, the definition, in terms of age ranges, of young healthy adults used to determine peak BMD has not been established [10].

Due to the absence of a consistent definition of young healthy adults in terms of age range, previous studies have used arbitrary reference standards for peak BMD calculated using data from subjects aged 20–29 years, 20–39 years, and 30–39 years or even from subjects from different ethnic groups [12–15, 17, 19]. The recommended reference range used by the International Osteoporosis Foundation and the International Society for Clinical Densitometry is the National Health and Nutrition Examination Survey (NHANES) III reference database for femoral neck measurements in white females aged 20–29 years. Although 20–29 years was used for the young healthy adult reference range in NHANES III, Japanese and Danish studies as well as Swedish and Chinese studies used 20–39 years for the reference group, corresponding to the GE Healthcare Lunar DXA system [10, 14, 19, 20]. A Norwegian study used 30–39 years for the young adult reference range, and an Estonian study used 25–39 years [13, 19]. A Thai study used an age group of 30–34 years for the reference range [12].

To obtain the exact age of peak BMD, we used a specific statistical method in this study, i.e., polynomial regression analysis. The results of our polynomial regression model indicated the age at which peak BMD is achieved in males for the total hip, femoral neck, and lumbar spine was 26, 20, and 20 years, respectively. The age at which peak BMD was achieved in females for the total hip, femoral neck, and lumbar spine was 36, 27 and 30 years, respectively. Results of the present study correspond well with those of earlier studies that reported peak BMD was achieved later in females than in males. For example, for the spine, age of peak BMD in Caucasian males was 22 years, while that in Caucasian females was 29 years [21]. This tendency also

was observed in a Chinese study that reported peak BMD was achieved in the 2nd decade of life in males and in the 3rd decade of life in females [22]. It has not been fully clarified why peak BMD is achieved later in females than in males. We consider that this may be attributable to hormonal effects [21, 23, 24], but this hypothesis is not evidence based. Further study is required to clarify this issue.

On the contrary, another previous study using the same statistical method reported that the age of peak BMD of the total hip, femoral neck, and lumbar spine was 32, 26, and 27 years, respectively, in Vietnamese males and 27, 22 and 27 years, respectively, in Vietnamese females [17]. These findings differ from those of our study, which demonstrated the age of peak BMD was younger in males than in females. It is possible that each ethnic group and body site has its own specific age at which the peak BMD is achieved; each ethnic group also may have its own specific peak BMD value. This issue needs to be investigated in a future study including more comprehensive factors, such as genetics, diet, physical activity, and lifestyle factors, as well as sex and ethnicity.

We calculated the peak BMD of each reference group using an age range commonly used in previous studies and compared the result with that of the polynomial regression model. The prevalence of osteoporosis differed according to the age range of the reference group in the Korean ethnic group. The prevalence of osteoporosis in the femoral neck in males was nearly two-fold higher when the Korean polynomial reference was used (7.1 %) compared to when the reference for 30–39 years of age was used (3.9 %). The prevalence of osteoporosis in the lumbar spine of females was 6 % higher when the Korean polynomial reference was used (25.3 %) compared to when the reference for 20–29 years of age was used (19.3 %). Thus, the present study shows that the prevalence of osteoporosis can be variable when using different age range references, even within an identical ethnic group. These results indicate that a consistent age range reference standard should be adopted. To do so, ethnic-specific references should be evaluated and the age range of the reference group standardized to compare the prevalence of osteoporosis and propose a treatment protocol. We propose that an established definition of 'young healthy adults' be determined and a consistent age range be used for calculating reference standard BMD and T-scores. We believe this will standardize treatment plans and healthcare costs. Ideally, the most appropriate reference standard BMD and T-scores will reflect the osteoporotic fracture risk and associated morbidity and mortality; however, this issue requires further study. For now, a more detailed and established definition of a reference standard BMD and T-score would promote the appropriate communication and interpretation of data between clinicians as well as healthcare policy.

This study has some limitations. First, we could not establish causal associations between the T-score of the BMD and fracture rates because of our cross-sectional study design. Furthermore, a longitudinal study is required to elucidate the clinical implications of different T-scores according to the different reference standards with regard to fracture rates. Second, cohort effects might have influenced the BMD levels of different age groups. A longitudinal study is needed to describe real BMD changes adjusted by age.

Acknowledgments This research was supported by the Ministry of Trade, Industry and Energy of Korea (grant nos. 10045220 and 10049711).

Conflict of interest All authors have no conflicts of interest to declare.

Ethical standards Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

References

1. Cummings SR, Melton LJ (2002) Epidemiology and outcomes of osteoporotic fractures. Lancet 359:1761–1767
2. Melton LJ 3rd (2003) Adverse outcomes of osteoporotic fractures in the general population. J Bone Miner Res 18:1139–1141
3. Johnell O, Kanis JA (2006) An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. Osteoporos Int 17:1726–1733
4. Dennison E, Cole Z, Cooper C (2005) Diagnosis and epidemiology of osteoporosis. Curr Opin Rheumatol 17:456–461
5. Gauthier A, Kanis JA, Jiang Y, Martin M, Compston JE, Borgstrom F, Cooper C, McCloskey EV (2011) Epidemiological burden of postmenopausal osteoporosis in the UK from 2010 to 2021: estimations from a disease model. Arch Osteoporos 6:179–188
6. Faulkner KG (2005) The tale of the T-score: review and perspective. Osteoporos Int 16:347–352
7. Kanis JA (1994) Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. WHO Study Group. Osteoporos Int 4:368–381
8. Genant HK, Engelke K, Fuerst T, Gluer CC, Grampp S, Harris ST, Jergas M, Lang T, Lu Y, Majumdar S, Mathur A, Takada M (1996) Noninvasive assessment of bone mineral and structure: state of the art. J Bone Miner Res 11:707–730
9. Mazess R, Collick B, Trempe J, Barden H, Hanson J (1989) Performance evaluation of a dual-energy x-ray bone densitometer. Calcif Tissue Int 44:228–232
10. Kanis JA, McCloskey EV, Johansson H, Oden A, Melton LJ 3rd, Khaltaev N (2008) A reference standard for the description of osteoporosis. Bone 42:467–475
11. Kanis JA, Melton LJ 3rd, Christiansen C, Johnston CC, Khaltaev N (1994) The diagnosis of osteoporosis. J Bone Miner Res 9:1137–1141
12. Namwongprom S, Rojnastein S, Mangklabruks A, Soontrapa S, Wongboontan C, Ongphiphadhanakul B (2012) Importance of ethnic base standard references for the diagnosis of osteoporosis in Thai women. J Clin Densitom 15:295–301

13. Kull M, Kallikorm R, Lember M (2009) Bone mineral density reference range in Estonia: a comparison with the standard database (NHANES III). J Clin Densitom 12:468–474
14. Ribom EL, Ljunggren O, Mallmin H (2008) Use of a Swedish T-score reference population for women causes a two-fold increase in the amount of postmenopausal Swedish patients that fulfill the WHO criteria for osteoporosis. J Clin Densitom 11:404–411
15. Noon E, Singh S, Cuzick J, Spector TD, Williams FM, Frost ML, Howell A, Harvie M, Eastell R, Coleman RE, Fogelman I, Blake GM, Substudy I-IB (2010) Significant differences in UK and US female bone density reference ranges. Osteoporos Int 21:1871–1880
16. Nam HS, Kweon SS, Choi JS, Zmuda JM, Leung PC, Lui LY, Hill DD, Patrick AL, Cauley JA (2013) Racial/ethnic differences in bone mineral density among older women. J Bone Miner Metab 31:190–198
17. Ho-Pham LT, Nguyen UD, Pham HN, Nguyen ND, Nguyen TV (2011) Reference ranges for bone mineral density and prevalence of osteoporosis in Vietnamese men and women. BMC Musculoskelet Disord 12:182
18. (1994) Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: report of a WHO Study Group. World Health Organ Tech Rep Ser 843:1−129
19. Emaus N, Omsland TK, Ahmed LA, Grimnes G, Sneve M, Berntsen GK (2009) Bone mineral density at the hip in Norwegian women and men–prevalence of osteoporosis depends on chosen references: the Tromso Study. Eur J Epidemiol 24:321–328
20. Zhang ZL, Qin YJ, Huang QR, Hu YQ, Li M, He JW, Zhang H, Liu YJ, Hu WW (2006) Bone mineral density of the spine and femur in healthy Chinese men. Asian J Androl 8:419–427
21. Henry YM, Fatayerji D, Eastell R (2004) Attainment of peak bone mass at the lumbar spine, femoral neck and radius in men and women: relative contributions of bone size and volumetric bone mineral density. Osteoporos Int 15:263–273
22. Mengmeng Z, Yagang L, Ying L, Xuena P, Binbin L, Liu Z (2012) A study of bone mineral density and prevalence of osteoporosis in Chinese people of Han nationality from Changchun. Arch Osteoporos 7:31–36
23. Kelly PJ, Twomey L, Sambrook PN, Eisman JA (1990) Sex differences in peak adult bone mineral density. J Bone Miner Res 5:1169–1175
24. Kastelan D, Grubic Z, Kraljevic I, Polasek O, Dusek T, Stingl K, Kerhin-Brkljacic V, Korsic M (2009) The role of estrogen receptor-alpha gene TA polymorphism and aromatase gene TTTA polymorphism on peak bone mass attainment in males: is there an additive negative effect of certain allele combinations? J Bone Miner Metab 27:198–204