Predicting Osteoporosis with Body Compositions in Postmenopausal Women: A Noninvasive Method

Wei-Hsiu Hsu

Chiayi Chang Gung Memorial Hospital

Wei-Bin Hsu

Chiayi Chang Gung Memorial Hospital

Chun-Hao Fan

Chiayi Chang Gung Memorial Hospital

Wen-Wei Robert Hsu (✉ wwh@cgmh.org.tw)

Chang Gung Memorial Hospital Chiayi Branch

Research article

Keywords: Basal metabolic rate, Fat-free mass, Fat mass, Osteoporosis, Postmenopausal women

Posted Date: December 9th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-43529/v2>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Version of Record: A version of this preprint was published on March 24th, 2021. See the published version at <https://doi.org/10.1186/s13018-021-02351-3>.

Abstract

Background: The prevalence of osteoporosis is rising steadily as the aging population increases. Bone mineral density (BMD) assessment is an established test for osteoporosis. However, the accessibility and radiation exposure limited its role in community screening. A more convenient approach for screening is suggested.

Methods: A total of 363 postmenopausal women over 50 age were included in this study and assessed with the body composition [including fat-free mass (FFM), fat mass (FM), and basal metabolic rate (BMR)] and BMD. Normal distributions and correlation coefficients among variables were calculated using the Shapiro-Wilk test and Pearson's correlation analysis, respectively. A receiver operating characteristic (ROC) curve was plotted and the area under ROC curves (AUC) was determined the optimal cut-off values of the body composition variables for osteoporosis prediction.

Results: The correlation coefficient of FFM, FM, FM ratio and BMR with femur neck T-score were 0.373, 0.266, 0.165, and 0.369, respectively while with spine T-score were 0.350, 0.251, 0.166, and 0.352, respectively ($p < 0.01$ for all). FFM, FM, and BMR showed an optimal cut-off value of 37.9 kg, 18.6 kg, and 1187.5 kcal for detecting osteoporosis.

Conclusions: The present study provided a model to predict osteoporosis in postmenopausal women and the optimal cut-off value of FFM, FM, and BMR could be calculated in Asian population. Among these factors, BMR seemed a better predictor than others. The BMR could be a target for exercise intervention in postmenopausal women for maintaining or improving BMD.

Trial registration: ClinicalTrials.gov, NCT02936336.

Registered 13 October 2016 -Retrospectively registered

Background

Osteoporosis is a common and silent skeletal disease characterized by bone mineral density (BMD) loss, resulting in fragile bone and high fracture risk (1-3). It is more prevalent in postmenopausal women as a result of estrogen deficiency. Indeed, the prevalence of osteoporosis is rising steadily resulting from aging population (4). However, osteoporosis also occurs in healthy premenopausal women, resulting from various factors such as nutrients, physical activity, medications, smoking, etc. (5, 6). It was estimated 200 million people suffered from osteoporosis and 8.9 million had osteoporotic fractures (7). Osteoporotic fracture has a high mortality, morbidity, and the increased cost of social care, and low health-related quality of life (1, 3, 8, 9). Early detection and interventions such as adequate calcium and vitamin D intake, bisphosphonates and monoclonal antibody medications, hormone-related therapy, and exercise are essential for geriatric welfare (10). According to the World Health Organization (WHO) guideline, osteoporosis diagnostic criteria and categories are based on BMD measurement. In general, dual-energy X-ray absorptiometry (DXA) is a hospital-based examination to estimate the BMD, while disadvantaged by its radiation exposure and limited accessibility in community. Although various questionnaire tools for screening have been developed, they are limited by inadequate specificity. Bioelectrical impedance analysis (BIA) is a commonly used method for

estimating body composition. Therefore, it is possible to improve the osteoporosis detection through BIA because its accessibility in community.

Fat mass (FM) has a positive correlation with BMD, especially in the elderly (11-13), and is more influential on the BMD than fat-free mass (FFM) be (14, 15). Some researchers pointed out that FFM is an important predictor for BMD without the age restriction (16, 17). Our previous study found out the basal metabolic rate (BMR) is closely associated with BMD in elderly persons, and claimed BMR might be a predictor for osteoporosis(18). Based on these results, the relationship between body composition and BMD was clarified and the parameters of body composition (FFM, FM, FM ratio, and BMR) have the potential to predict BMD. But it is unclear that what the cut-off values of FFM, FM, FM ratio and BMR are for osteoporosis prediction. Because the prevalence of osteoporosis in women is higher than in men(19). Here, we undertook this pilot study to determine the cut-off values of FFM, FM, BMR, and FM ratio from body composition, non-invasive assessment, to predict osteoporosis.

Methods

Participants

This cross-sectional study was performed at the Chia-Yi Chang Gung Memorial Hospital. All participants were assessed with the BMD measurement and body composition. Based on the WHO osteoporosis definition, the subjects whose T-score > -2.5 were divided into the non-osteoporosis group while T-score < -2.5 into osteoporosis group. All participants were enrolled from the rural community from southern Taiwan between August 2010 and December 2012. The inclusion criteria were physically independent postmenopausal women aged over 50-year-old. The exclusion criteria were women taking any medications predisposing to poor bone quality, undergoing any medical therapies of osteoporosis and hormone-replacement therapy, with cognitive impairment and diabetes mellitus, and having bone fracture history. This study was approved by the Ethics Committee and Institutional Review Board of the Chang Gung Memorial Hospital (IRB 99-3951B) and registered in the ClinicalTrials.gov (ID: NCT02936336). The written informed consent was obtained from all individual participants included in the study.

BMD measurement

DXA (QDR 4500A; Hologic, Waltham, MA, USA) was performed to measure the BMD of the proximal femur (femoral neck) and lumbar spine (L2-L4) by an experienced and qualified radiographer (Figure 1). By the definition from the World Health Organization, a BMD T-score of -2.5 or below is diagnosed as osteoporosis.

Body composition

An eight-polar tactile-electrode impedance meter (InBody 720, Biospace, Seoul, Korea) was used to assess the body composition and simultaneously recorded body weight, FFM, total body water, and regional fat mass, and BMR (18).

Statistical analysis

Normal distributions were calculated using the Shapiro-Wilk test. Pearson's correlation analysis was used to calculate the correlation coefficients among variables. By the World Health Organization definition (osteoporosis: T-score ≤ -2.5 ; osteopenia: T-score ≤ -1 and > -2.5 ; normal: T-score > -1), the participants in this study were divided into two groups, non-osteoporosis (non-OP) and osteoporosis (OP). A receiver operating characteristic (ROC) curve was plotted with non-OP as positive and OP as negative to assess the diagnostic value of the predictors FFM, FM, BMR, and FM ratio. The area under the ROC curves (AUC) was calculated to evaluate the predictive performance of the variables. The points on the fit curve closest to the left upper corner were defined as cut-off points for the diagnosis of osteoporosis. All data analysis was performed using the Statistical Package for the Social Sciences Windows, version 17.0 (SPSS, Chicago, IL, USA). All continuous data were presented as the mean $\pm$ SD. The statistical analysis was performed by CHF.

Results

Between August 2010 and December 2012, all participants were enrolled from the rural community from southern Taiwan. A total of 363 postmenopausal women over 50 age were included in this study. Based on the WHO osteoporosis definition, 211 subjects whose T-score > -2.5 were classified as non-osteoporosis group and 152 subjects whose T-score < -2.5 as osteoporosis group. The subjects' demography is shown in Table 1. The average of subjects' age is 64.1 years, a body mass index (BMI) is 24.7 kg/m². The women had mean T-score of femur neck and spine are respectively -1.9 ± 1.0 and -1.8 ± 1.4 . Their mean FFM, FM, and FM ratio are respectively 38 ± 4 kg, 21.2 ± 6.3 kg, and $35 \pm 7\%$, while the mean of BMR is 1182.7 ± 88.9 kcal. Age, height, weight, BMI, Femur neck T-score (FNTS), Spine T-score (STS), FFM, FF, and BMR had significant differences between the two groups. So, we assessed the relationship between BMD T-score (femur neck and spine) and other variables by Pearson correlation analysis. As shown in Table 2, Age is negatively correlated with FNTS and STS while other variables are positively correlated with FNTS and STS ($p < 0.01$ for all). The correlation coefficient of FFM, FM, FM ratio and BMR with femur neck T-score were 0.373, 0.266, 0.165, and 0.369, respectively while with spine T-score 0.350, 0.251, 0.166, and 0.352, respectively.

ROC curve analysis was performed to estimate the optimal cut-off value of FFM, FM, FM ratio, and BMR for predicting osteoporosis. As shown in Table 3 and Figure 2, FFM showed an optimal sensitivity (0.588) and specificity (0.73) at the cut-off value of 37.9 kg (AUC=0.700, 95%CI: 0.646-0.753). FM revealed an optimal sensitivity (0.73) and specificity (0.47) at the cut-off value of 18.6 kg (AUC=0.602, 95%CI: 0.542-0.661). BMR presented an optimal sensitivity (0.59) and specificity (0.73) at the cut-off value of 1187.5 kcal (AUC=0.701, 95%CI: 0.647-0.754) while FM ratio did not statistically predict osteoporosis.

Discussion

Previous studies reported that FM is related to the BMD of the lumbar spine and proximal femur (20, 21). Besides, other studies showed that BMR is more closely related to BMD than FFM, FM, and BMI (18, 22, 23). Our results were echoed to these studies and revealed that BMR could be effective to predict osteoporosis (BMD T-score < -2.5) with the optimal cut-off value 1187.5 kcal (Table 3 and Figure 2) in women over 50-old-year. If their BMR was lower than the cut-off values 1187.5 kcal, they might have a high risk of osteoporosis.

As mentioned above, higher FM went along with higher BMD as an effective predictor for osteoporosis but some studies showed that FM was not effective for osteoporosis prediction in middle-aged and elderly people in Asia (24, 25) and the increased central body FM was negatively associated with BMD (26). Moreover, Saarelainen and his colleagues reported that trunk FM is positively related to lumbar spine BMD, but not to the hip BMD and body weight in postmenopausal women (21). Kirchengast and his colleagues found out that the relationship between FM and BMD only occurred in elder women (27). These studies showed that the FM for osteoporosis prediction might be restricted by ethnicity, gender, the region of FM, etc. However, FFM has a stronger positive relation with BMD at all ages in Chinese men and women (28) and our results (Table 3) also showed that the AUC of FFM (0.700) was higher than FM (0.602), suggesting that FFM seems to be better than FM for osteoporosis prediction. However, BMD is influenced by multiple factors such as genetic factors, gender, diet physical activity, medical diseases, stress, etc. (5, 29). It seemed the BMR is not the sole determine factor for osteoporosis that the correlation coefficient between all body composition variable and BMD T-score was <0.4 . However, it did provide a window for screening osteoporosis through convenient and non-invasive methodology.

BMR, the amount of energy expended, is predicted with regarding to resting energy expenditure. In multivariate analysis, BMR was low correlated with FM (Correlation coefficient:0.281) (Table2), suggesting that BMR and FM might be independent predictors of osteoporosis. However, BMR is more closely associated with BMD in elderly persons than BMI, FM, and FFM (18, 22, 23). BMR is positively associated with muscle strength (30) while muscle strength and BMD also are correlated (31, 32). Our results also showed that the AUC of BMR is higher than FFM, and FM, suggesting that BMR might be a good predictor for osteoporosis. According to our results, we proposed that if the postmenopausal woman's BMR is lower than the cut-off value, 1187.5 kcal, the subject might have higher osteoporosis risk than others whose over 1187.5 kcal.

Although hip and spine fractures are a portion of osteoporotic fractures, these fractures have a huge impact on the patient's daily activity and medical burden (33, 34). Low BMD is associated with an increased risk of fracture and hence provided an measurable method in osteoporotic fractures preventions. However, it is disadvantage by radiation exposure and limited accessibility. Since BMR could well predict BMD in the present study, it seemed a good method in screening osteoporosis. Besides, the American College of Sports Medicine (ACSM) proposes that increasing physical exercise can maintain and improve bone quality in response to bone health problems (35). Here, we provided the cut-off value of 1187.5 kcal of BMR. It could serve as a target value for exercise intervention to enhance BMR in postmenopausal women to maintain and improve their BMD.

Several limitations of the present study should be acknowledged. First, the subjects of this study are postmenopausal women aged over 50 years old. Men and those under 50 years old are not included. Therefore, the relevant threshold only applies to postmenopausal women aged over 50 years old. Second, because the subjects were from southern Taiwan, the present cut-off value was restricted to Asians. It was shown that the body compositions were not identical between Caucasian and Asian populations. (36-38). In fact, Asian populations had more fat mass percentage and central fat. Therefore, extrapolating the findings in the present study to Caucasian populations warranted further investigations. Nevertheless, the effect of the exercise on the BMD has no difference in different races so we proposed that the BMR could be a predictor for BMD in different races via slightly adjusting the cut-off value of BMR.

Conclusions

In the present study, our results showed that BMR was a better predictor for osteoporosis than other body composition, including FM, FM ratio, and FFM. We proposed that the BMR could serve as a screening tool to alert the risk of osteoporosis and early intervention for osteoporosis. Simultaneously, the cut-off value of BMR also could be a target value for exercise intervention to enhance BMR in postmenopausal women to maintain or improve their BMD. In addition, clinical risk assessment instruments, such as Osteoporosis Self-Assessment Tool, the Simple Calculated Osteoporosis Risk Estimation instrument, the Osteoporosis Self-Assessment Tool for Asians, and the Osteoporosis Risk Assessment Instrument, had all high sensitivity exceeding 90% for identifying individuals with DXA-determined osteoporosis or low BMD but low specificity at thresholds required for high sensitivity (39). It is possible to include this objective data such as BMR to enhance sensitivity and specificity in osteoporosis screening.

Abbreviations

BMD: Bone mineral density, FFM: Fat-free mass, FM: Fat mass, BMR: Basal metabolic rate, ROC: Receiver operating characteristic, AUC: Area under the ROC curves, BMI: Body mass index, ACSM: American College of Sports Medicine.

Declarations

Ethics approval and consent to participate

This retrospective study was approved by the Ethics Committee and Institutional Review Board of the Chang Gung Memorial Hospital (IRB 99-3951B), and all patients provided written informed consent. The study protocol was also registered in the ClinicalTrials.gov (ID: NCT02936336).

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request

Competing interests

All authors declare that they have no competing interests.

Funding

This work was supported by Chang Gung Memorial Hospital Grant CMRPG690111-3 and CORPG6F0011-13 are appreciated. There was no external funding.

Authors' contributions

WHH and WBH drafted the manuscript and revised it critically for important intellectual content. WBH and CHF analyzed and interpreted the data. WHH and RWWH contributed substantially to the conception and design of the study. All authors read and approved the final manuscript.

Acknowledgments

Not applicable

References

1. Cauley JA. Public health impact of osteoporosis. *J Gerontol A Biol Sci Med Sci*. 2013;68(10):1243-51.
2. Schmitt NM, Schmitt J, Doren M. The role of physical activity in the prevention of osteoporosis in postmenopausal women-An update. *Maturitas*. 2009;63(1):34-8.
3. Compston J, Cooper A, Cooper C, Francis R, Kanis JA, Marsh D, et al. Guidelines for the diagnosis and management of osteoporosis in postmenopausal women and men from the age of 50 years in the UK. *Maturitas*. 2009;62(2):105-8.
4. Hernlund E, Svedbom A, Ivergard M, Compston J, Cooper C, Stenmark J, et al. Osteoporosis in the European Union: medical management, epidemiology and economic burden. A report prepared in collaboration with the International Osteoporosis Foundation (IOF) and the European Federation of Pharmaceutical Industry Associations (EFPIA). *Arch Osteoporos*. 2013;8:136.
5. Vondracek SF, Hansen LB, McDermott MT. Osteoporosis risk in premenopausal women. *Pharmacotherapy*. 2009;29(3):305-17.
6. Biz C, Berizzi A, Crimi A, Marcato C, Trovarelli G, Ruggieri P. Management and treatment of femoral neck stress fractures in recreational runners: a report of four cases and review of the literature. *Acta Biomed*. 2017;88(4S):96-106.
7. Pisani P, Renna MD, Conversano F, Casciaro E, Di Paola M, Quarta E, et al. Major osteoporotic fragility fractures: Risk factor updates and societal impact. *World J Orthop*. 2016;7(3):171-81.
8. Johnell O, Kanis JA. An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. *Osteoporos Int*. 2006;17(12):1726-33.
9. Wang CB, Lin CF, Liang WM, Cheng CF, Chang YJ, Wu HC, et al. Excess mortality after hip fracture among the elderly in Taiwan: a nationwide population-based cohort study. *Bone*. 2013;56(1):147-53.
10. Tu KN, Lie JD, Wan CKV, Cameron M, Austel AG, Nguyen JK, et al. Osteoporosis: A Review of Treatment Options. *P T*. 2018;43(2):92-104.
11. Cui LH, Shin MH, Kweon SS, Park KS, Lee YH, Chung EK, et al. Relative contribution of body composition to bone mineral density at different sites in men and women of South Korea. *J Bone Miner Metab*. 2007;25(3):165-71.

12. Gonnelli S, Caffarelli C, Tanzilli L, Alessi C, Tomai Pitinca MD, Rossi S, et al. The associations of body composition and fat distribution with bone mineral density in elderly Italian men and women. *J Clin Densitom.* 2013;16(2):168-77.
13. Lekamwasam S, Weeraratna T, Rodrigo M, Arachchi WK, Munidasa D. Association between bone mineral density, lean mass, and fat mass among healthy middle-aged premenopausal women: a cross-sectional study in southern Sri Lanka. *J Bone Miner Metab.* 2009;27(1):83-8.
14. Douchi T, Yamamoto S, Oki T, Maruta K, Kuwahata R, Yamasaki H, et al. Difference in the effect of adiposity on bone density between pre- and postmenopausal women. *Maturitas.* 2000;34(3):261-6.
15. Douchi T, Yonehara Y, Kawamura Y, Kuwahata A, Kuwahata T, Iwamoto I. Difference in segmental lean and fat mass components between pre- and postmenopausal women. *Menopause.* 2007;14(5):875-8.
16. Cheng Q, Zhu YX, Zhang MX, Li LH, Du PY, Zhu MH. Age and sex effects on the association between body composition and bone mineral density in healthy Chinese men and women. *Menopause.* 2012;19(4):448-55.
17. Genaro PS, Pereira GA, Pinheiro MM, Szejnfeld VL, Martini LA. Influence of body composition on bone mass in postmenopausal osteoporotic women. *Arch Gerontol Geriatr.* 2010;51(3):295-8.
18. Hsu WH, Fan CH, Lin ZR, Hsu RW. Effect of basal metabolic rate on the bone mineral density in middle to old age women in Taiwan. *Maturitas.* 2013;76(1):70-4.
19. Wade SW, Strader C, Fitzpatrick LA, Anthony MS, O'Malley CD. Estimating prevalence of osteoporosis: examples from industrialized countries. *Arch Osteoporos.* 2014;9:182.
20. Nur H, Toraman NF, Arica Z, Sarier N, Samur A. The relationship between body composition and bone mineral density in postmenopausal Turkish women. *Rheumatol Int.* 2013;33(3):607-12.
21. Saarelainen J, Honkanen R, Kroger H, Tuppurainen M, Jurvelin JS, Niskanen L. Body fat distribution is associated with lumbar spine bone density independently of body weight in postmenopausal women. *Maturitas.* 2011;69(1):86-90.
22. Yilmaz B, Yasar E, Goktepe AS, Onder ME, Alaca R, Yazicioglu K, et al. The relationship between basal metabolic rate and femur bone mineral density in men with traumatic spinal cord injury. *Arch Phys Med Rehabil.* 2007;88(6):758-61.
23. Quirino MA, Modesto-Filho J, de Lima Vale SH, Alves CX, Leite LD, Brandao-Neto J. Influence of basal energy expenditure and body composition on bone mineral density in postmenopausal women. *Int J Gen Med.* 2012;5:909-15.
24. Kim JH, Choi HJ, Kim MJ, Shin CS, Cho NH. Fat mass is negatively associated with bone mineral content in Koreans. *Osteoporos Int.* 2012;23(7):2009-16.
25. Yoo HJ, Park MS, Yang SJ, Kim TN, Lim KI, Kang HJ, et al. The differential relationship between fat mass and bone mineral density by gender and menopausal status. *J Bone Miner Metab.* 2012;30(1):47-53.
26. Fu X, Ma X, Lu H, He W, Wang Z, Zhu S. Associations of fat mass and fat distribution with bone mineral density in pre- and postmenopausal Chinese women. *Osteoporos Int.* 2011;22(1):113-9.
27. Kirchengast S, Huber J. Sex-specific associations between soft tissue body composition and bone mineral density among older adults. *Ann Hum Biol.* 2012;39(3):206-13.

28. Hu WW, Zhang H, Wang C, Gu JM, Yue H, Ke YH, et al. Lean mass predicts hip geometry and bone mineral density in chinese men and women and age comparisons of body composition. *J Clin Densitom.* 2012;15(4):434-42.
29. Pouresmaeili F, Kamalidehghan B, Kamarehei M, Goh YM. A comprehensive overview on osteoporosis and its risk factors. *Ther Clin Risk Manag.* 2018;14:2029-49.
30. Oh SK, Son DH, Kwon YJ, Lee HS, Lee JW. Association between Basal Metabolic Rate and Handgrip Strength in Older Koreans. *Int J Environ Res Public Health.* 2019;16(22).
31. Rikkonen T, Sirola J, Salovaara K, Tuppurainen M, Jurvelin JS, Honkanen R, et al. Muscle strength and body composition are clinical indicators of osteoporosis. *Calcif Tissue Int.* 2012;91(2):131-8.
32. Chen L, Nelson DR, Zhao Y, Cui Z, Johnston JA. Relationship between muscle mass and muscle strength, and the impact of comorbidities: a population-based, cross-sectional study of older adults in the United States. *BMC Geriatr.* 2013;13:74.
33. Cannada LK, Hill BW. Osteoporotic Hip and Spine Fractures: A Current Review. *Geriatr Orthop Surg Rehabil.* 2014;5(4):207-12.
34. Bano G, Dianin M, Biz C, Bedogni M, Alessi A, Bordignon A, et al. Efficacy of an interdisciplinary pathway in a first level trauma center orthopaedic unit: A prospective study of a cohort of elderly patients with hip fractures. *Arch Gerontol Geriatr.* 2020;86:103957.
35. Kohrt WM, Bloomfield SA, Little KD, Nelson ME, Yingling VR, American College of Sports M. American College of Sports Medicine Position Stand: physical activity and bone health. *Med Sci Sports Exerc.* 2004;36(11):1985-96.
36. Liang MT, Bassin S, Dutto D, Braun W, Wong N, Pontello AM, et al. Bone mineral density and leg muscle strength in young Caucasian, Hispanic, and Asian women. *J Clin Densitom.* 2007;10(2):157-64.
37. Morimoto Y, Maskarinec G, Conroy SM, Lim U, Shepherd J, Novotny R. Asian ethnicity is associated with a higher trunk/peripheral fat ratio in women and adolescent girls. *J Epidemiol.* 2012;22(2):130-5.
38. Hunma S, Ramuth H, Miles-Chan JL, Schutz Y, Montani JP, Joonas N, et al. Body composition-derived BMI cut-offs for overweight and obesity in Indians and Creoles of Mauritius: comparison with Caucasians. *Int J Obes (Lond).* 2016;40(12):1906-14.
39. Nayak S, Edwards DL, Saleh AA, Greenspan SL. Systematic review and meta-analysis of the performance of clinical risk assessment instruments for screening for osteoporosis or low bone density. *Osteoporos Int.* 2015;26(5):1543-54.

Tables

Table 1 Demographics for subjects (N=363)						
	Total subjects (N=363)		Non- osteoporosis (N=211)		Osteoporosis (N=152)	
	Mean	±SD	Mean	±SD	Mean	±SD
Age (years)	64.1	±8.3	62.0	±8.0	66.9	±7.9 *
Height (cm)	154.7	±5.2	155.5	±5.3	153.5	±4.7 *
Weight (kg)	59.0	±8.5	61.0	±8.4	56.3	±8.0 *
BMI	24.7	±3.4	25.2	±3.4	24.0	±3.3 *
FNTS	-1.9	±1.0	-1.3	±0.7	-2.7	±0.7 *
STS	-1.8	±1.4	-1.0	±1.1	-2.8	±1.1 *
FM ratio (%)	35.4	±6.7	35.9	±6.4	34.7	±7.1
FFM (kg)	37.6	±4.1	38.8	±4.2	36.0	±3.4 *
FF (kg)	21.2	±6.3	22.2	±6.2	19.9	±6.3 *
BMR (k cal)	1182.7	±88.9	1207.3	±90.7	1148.5	±73.9 *
BMR: Basal metabolic rate, FFM: Fat-free mass, FM: Fat mass, FM ratio: Fat mass ratio, FNTS: Femur neck T-score, STS: Spine T-score.						
* $p \leq 0.05$ between non- osteoporosis and osteoporosis						

Table 2 Correlation coefficients between variables and BMD T-score (<i>r</i>)										
	FNTS	STS	Age	Height	Weight	BMI	FM ratio	FM	BMR	FFM
FNTS	1									
STS	.619**	1								
Age	-.353**	-.222**	1							
Height	.200**	.180**	-.206**	1						
Weight	.356**	.345**	-.064	.348**	1					
BMI	.255**	.265**	.029	-.123*	.874**	1				
FM ratio	.165**	.166**	.069	-.205**	.646**	.773**	1			
FM	.266**	.251**	.038	.001	.859**	.894**	.908**	1		
BMR	.369**	.352**	-.151**	.627**	.662**	.387**	-.066	.281**	1	
FFM	.373**	.350**	-.160**	.621**	.665**	.393**	-.054	.284**	.995**	1
BMR: Basal metabolic rate, FFM: Fat-free mass, FM: Fat mass, FM ratio: Fat mass ratio, FNTS: Femur neck T-score, STS: Spine T-score.										
* $p \leq 0.05$ ** $p \leq 0.01$										

Table 3 Area under curve (AUC) of BMR, fat-free mass and Fat mass as a single predictor for each measurement site from ROC analysis

Variable	AUC	Cut-point	1-Specificity	Sensitivity	95.0% CI	
					Lower	Upper
FFM	.700**	37.9 kg	.270	.588	.646	.753
FM	.602**	18.6 kg	.533	.730	.542	.661
FM ratio	.538	26.7 %	.829	.934	.477	.599
BMR	.701**	1187.5 kcal	.270	.597	.647	.754

FFM: Fat-free mass, FM: Fat mass, FM ratio: Fat mass ratio, BMR: Basal metabolic rate.

** $p < 0.01$

Figures

(A)

(B)

Figure 1

The example of BMD measurement (A) femoral neck and (B) lumbar spine L2-L4 by DXA in female aged 69.

Figure 2

ROC analysis to identify the optimal cut-off value of FFM, FM, FM ratio, and BMR to osteoporosis.