The Abdominal Obesity and the Bone Mineral Density are Negatively Correlated by the Factors of Gender and Menopause in Korean Adults

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Abstract

Objectives: Osteoporosis is one of the key problems of public health in the elderly. This study was performed to understand how abdominal obesity affects bone mineral density (BMD). Methods: We selected 6,333 participants aged 19–93 years (2,908 men, 1,987 pre-menopausal and 1,438 post-menopausal women) from the data of the Korea National Health and Nutrition Examination Survey IV (KNHANES 2008–2009). Waist circumference value was set as an index of abdominal obesity. Demographic, social, and clinical parameters were investigated as potential risk factors of BMD. Findings: BMD were positively affected by exercise, income, and education (p<0.001). Women's fat mass (FM) showed a positive correlation with BMD. The total lean mass (TLM) of all groups strongly correlated to BMD (p<0.0001). Our models suggest that abdominal obesity has a strong negative relationship with BMD in Korean men and pre-menopausal women with statistical significance (standardized β = -0.111, P<0.0001 and standardized β = -0.097, P<0.0001, respectively) but not in the case of postmenopausal women. A narrow waist and lean body weight favor high BMD. Applications: Our study suggests that separate preventive programs should be recommended for each group of men and pre- and post-menopausal women in Korea.

Keywords: Abdominal Obesity, Bone Mineral Density, Fat Mass, Lean Mass

1. Introduction

Bone fractures caused by osteoporosis constitute a significant public health problem, especially in the elderly population. The Korea National Health and Nutrition Examination Survey (KNHANES) conducted from 2008 to 2009 reported the prevalence of osteoporosis are 35.5% for women and 7.5% for men in adults of more than 50 years old according to the diagnosis of osteopenia or osteoporosis based on the T-score criteria defined by the World Health Organization. This is similar to findings for the other countries in East Asia, but higher than findings for whites. During the 2008-2009 periods, the residual lifetime risk of osteoporosis-associated fractures for 50 years old Korean individuals was predicted at 59.5% for women and 23.8% for men, which...
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constitutes a significant socio-economic burden for Korea.

One of the most powerful predictive markers of osteoporotic fractures is bone mineral density (BMD)\(^1\), which is positively correlated to overall body weight; the single most important risk factor for osteoporosis is underweight\(^2\). However, it is unclear whether fat or lean mass affects the bone density with great impact. It is reported more about the different effects regional-specific fat mass has in both animals and humans\(^3-10\). At a younger age, anthropometric indices predict metabolic syndrome with different sensitivity and specificity, but at elderly people, the index with significant correlation with metabolic syndrome is waist circumference\(^11\). For example, abdominal obesity, unlike subcutaneous adipose tissue, is characterized by storage of fat around visceral adipose tissue or intra-abdominal organs\(^12\). These fat stores secrete adipokine and are easily metabolized. Once they enter the bloodstream, they cause fatty liver, increase serum free fatty acid, playing an important role in the pathogenesis such as insulin resistance, diabetes mellitus, and cardiovascular disease\(^13\). This is likely due to the insulin resistance caused by low estrogen production during menopause in women\(^14\). Ethnicity has a significant impact on the abdominal adiposity and liver fat partitioning, and East Asians’ abdominal fat distribution is the most deleterious. Despite lower absolute values of BMI, East Asians presented the largest accumulation of visceral adipose tissue. On the other hand, the accumulation of their deep subcutaneous adipose tissue was the lowest with increasing adiposity\(^15\). Visceral obesity has also been reported to increase osteopenia and osteoporosis\(^8,10,12-15\). The effects of fat on bone density seem to vary in form and range depending on the subject’s race, age, and gender\(^4,16-17\). The KNHANES 2008-2009 database is yielding important information on the etiology of chronic disease. A recent analysis of this database revealed that social factors have effects on the prevalence of osteoporosis in Korea\(^18\).

In this study, we analyzed the association between osteoporosis and abdominal obesity using a plenty number of variables, including demographic, social, clinical factors, etc., to identify the predominant risk factor for BMD of the Korean population and understand the obesity-osteoporosis relationship.

2. Subjects and Methods

2.1 Subject Selection

This study was performed analyzing the data obtained from the KNHANES IV, which used a design of rolling sampling with a complex, stratified, multistage, probability-cluster survey. The subject was a representative sample of the non-institutionalized population of South Korea.

Detailed information on survey design has previously been provided\(^19\). In total, 10,533 responders participated in the survey. Of these, 7,890 were aged 19 years and above. However, 1,557 responders were excluded because they had been previously diagnosed with tumor, thyroid disease, chronic hepatic disease and chronic kidney failure and they were taking medicines expected to affect their health and bone metabolism. Ultimately, we selected 6,333 participants aged 19-93 years (2,908 men, 1,987 pre-menopausal and 1,438 post-menopausal women). Participants were given explanation of the purpose of the research and they provided written informed consent as required by the Korean Ministry of Health and Welfare. The study was performed in compliance with the Ethical Principles for Medical Research Involving Human Subjects, as specified by the Helsinki Declaration.

2.2 Anthropometric Measurement

It was measured to the nearest 0.1 cm or 0.1 kg for the height and weight of each person, wearing a light robe and no shoes. We used waist circumference (WC) to evaluate abdominal obesity, since this characteristic is easily measured and is known to be an accurate indicator of fat mass\(^20,21\). Waist circumference was taken by locating the measuring tape horizontally parallel to the floor between the lowest rib and and above the iliac crest\(^22\). Blood pressure was measured in the seated state after more than twice the 10 minutes break of relaxation. BMD measurements of the central skeletal sites lumbar spine (L-spine) and femoral neck (T-femur) and body composition, total lean mass (TLM), total fat mass (TFM) were taken by dual-energy X-ray absorptiometry (DXA;
DISCOVERY-W fan-beam densitometer; Hologic, Bedford, MA) according to standard procedures. The DXA measurements were daily calibrated with phantom supplied by the manufacturer. The within-day coefficients of variation (%) for double-repetitive measurements of 30 adults performed by four examiners ranged from 0.84 to 2.29\cite{23}. All radiologists had been trained to minimize error, in accordance with the criteria recommended by the International Society for Clinical Densitometry.

2.3 Biochemical Measurements
Fasting blood glucose (FBS), HDL cholesterol and triglyceride (TG) were measured from the plasma samples separated from the blood by centrifugation immediately after sampling of it in the morning after more than 10 hours-overnight fasting. Blood sample was analyzed using an Advia 1650/2400 (Siemens, New York, NY) in the KNHANES IV. The intraassay and interassay coefficients of variation (CVs) for this analysis were less than 2\%\cite{23}.

2.4 Covariates
Based on prior studies that reported on risk factors known to have effects on bone health\cite{24,25}, in this study, demographic and medical risk factors related with reduced BMD were considered to have a potential influence on its risks. Besides age, weight, height, TFM, and TLM, other important covariates included: smoking status (e.g., whether participants were current/former smokers or had never smoked), drinking status (defined as never, moderate, heavy drinking), regular physical activity (defined as moderate-intensive activity \(\geq\) 30 minutes once and more than twice a week; yes vs. no), monthly income (whether subjects earned <3 million won per month), education level (whether the participant had graduated from high school; yes vs. no), Metabolic parameters were considered to be potentially relevant risk factors since the NCEP-ATP III criteria define them as covariates\cite{26,27}. We redefined the abdominal obesity and hyperglycemia in accordance with the Asia-Pacific criteria\cite{27} and American Diabetes Association 2003 guidelines\cite{28}, respectively: abdominal obesity (WC >90 cm in men and >85 cm in women), hyperglycemia (fasting glucose \(\geq\) 100 mg/dL), hypertriglyceridemia (triglyceride \(\geq\) 150 mg/dL), low high-density lipoprotein (HDL) (cholesterol < 40 mg/dL in men and cholesterol < 50 mg/dL in women), and hypertension (high blood pressure \(\geq\) 130/85 mmHg).

2.5 Statistical Analysis
Statistical analyses were conducted using SPSS v.18.0 (PASW statistics 18.0.0, IBM Corporation, NY, USA). This software package allowed us to incorporate information on sample weights to produce estimates on the representative of the Korean population. We created 2 different models in order to see the correlation between BMD and abdominal obesity (WC); each model used multivariate regression after adjusting for potentially influencing variables\cite{24,25}. Adjustments for age, weight, and height were done in Model I. After the adjustments for all parameters done for Model I were applied to Model II. And then Model II was adjusted for all were covariates among that appeared to be significantly influential for each group in the following variables: smoking status, drinking status, monthly income, physical activity level, education level and metabolic parameters (HDL-cholesterol, fasting glucose, triglyceride levels, SBP, and DBP). The existence of a correlation between WC quartiles and BMD was tested by ANCOVA for the two BMD parameters. WC quartile values were divided as follows: (1\textsuperscript{st}) <78.2; (2\textsuperscript{nd}) 78.2-84.1; (3\textsuperscript{rd}) 84.2-90.1 (4\textsuperscript{th}) \(\geq\)90.2 for men (1\textsuperscript{st}) < 71.2; (2\textsuperscript{nd}) 71.2-77.8; (3\textsuperscript{rd}) 77.9-84.8 (4\textsuperscript{th}) \(\geq\)84.9 for women. In the analysis, we adjusted for age, height, TFM, TLM, and metabolic parameters (HDL-cholesterol, fasting glucose, triglyceride, SBP, and DBP). We used one-way analysis of variance (ANOVA), analysis of covariance (ANCOVA), and multivariate linear regression analyses to evaluate the relationship between abdominal obesity and both of L-spine and T-femur BMD. Statistically meaningful significance was determined when \(p < 0.05\).

3. Results
The subjects were separated into three groups based on sex and menopausal status and were separately analyzed: men (46%, predominantly in their forties),
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pre-menopausal women (31%), and postmenopausal women (23%) (Table 1). The three groups differed with respect to most parameters. First, men were significantly heavier and taller than pre-menopausal and postmenopausal women (p<0.001, respectively). On the other hand, men had lower TFM (p<0.001) and higher TLM (p<0.001) than both groups of women. Nonetheless, pre-menopausal women had significantly smaller WCs than men and post-menopausal women (p<0.001, respectively). Menopause was associated with 10% reduced BMD of the L-spine and T-femur. This analysis suggests that gender and menopause must be considered when examining the relationship between WC and BMD parameters.

The correlation coefficients between bone mineral density (BMD) and general clinical parameters affected by gender and menopause were revealed to indicate that these parameters are significantly correlated with each other (Table 2). Furthermore, components of body composition also significantly correlated with BMD. Whereas age, height, and WCs established a correlation negatively with BMD, fat and lean mass did positively. Age in L-spine of men, age in T-femur of pre-menopausal women, height in L-spine of post-menopausal women was not significantly correlated with BMD.

ANOVA analysis revealed that the demographic and social factors related to BMD varying with gender

### Table 1. Characteristics of Study Subjects

|                | Men (N = 2908) | Premenopausal women (N = 1987) | Postmenopausal women (N = 1438) | p-value |
|----------------|---------------|-------------------------------|---------------------------------|---------|
| Age (years)    | 43.61±0.41    | 35.38±0.28                    | 63.05±0.37                     | <.0001  |
| Weight (kg)    | 70.13±0.26    | 57.33±0.25                    | 57.11±0.28                     | <.0001  |
| Height (cm)    | 170.67±0.16   | 159.43±0.15                   | 153.07±0.21                    | <.0001  |
| TFM (kg)       | 15.24±0.15    | 18.20±0.19                    | 19.45±0.18                     | <.0001  |
| TLM (kg)       | 54.07±0.19    | 38.55±0.15                    | 37.12±0.17                     | <.0001  |
| WC (cm)        | 83.88±0.27    | 74.82±0.31                    | 82.42±0.38                     | <.0001  |
| L-spine BMD (g/cm²) | 43.61±0.41   | 35.38±0.28                    | 63.05±0.37                     | <.0001  |
| T-femur BMD (g/cm²) | 70.13±0.26   | 57.33±0.25                    | 57.11±0.28                     | <.0001  |

All values were estimated based on weighted mean ± weighted SEM. TFM: total fat mass; TLM: total lean mass; WC: waist circumference; L-spine BMD: lumbar spine bone mineral density; T-femur BMD: total femur bone mineral density

### Table 2. Correlation Coefficients between Bone Mineral Density (BMD) And General Clinical Parameters Affected by Gender and Menopause

| Variable | Men | Premenopausal women | Postmenopausal women |
|----------|-----|---------------------|----------------------|
|          | BMD | BMD                 | BMD                  |
|          | L-spine | T-femur | L-spine | T-femur | L-spine | T-femur |
| Age      | -0.010 | -0.127** | 0.047* | -0.014 | -0.258** | -0.378** |
| Height   | -0.036* | -0.144** | -0.059* | -0.167** | -0.024 | -0.084** |
| TFM      | 0.044* | 0.041* | 0.088** | 0.124** | 0.149** | 0.124** |
| TLM      | 0.241** | 0.345** | 0.239** | 0.295** | 0.165** | 0.226** |
| WC       | -0.039* | -0.059** | -0.056* | -0.069** | -0.080** | -0.081** |

Note: all, *p value < 0.05, **p value< 0.01
Table 3. Impact of the Demographic and Socio-Cultural Risk Factors of Lumbar Spine and Total Femur Bone Mineral Density (BMD) by Gender and Menopause

| Variable                  | Men (N = 2,908) | Premenopausal women (N = 1,987) | Postmenopausal women (N = 1,438) |
|---------------------------|-----------------|---------------------------------|---------------------------------|
|                           | BMD             | BMD                             | BMD                             |
|                           | L-spine         | T-femur                         | L-spine                         | T-femur                         | L-spine | T-femur |
| Smoking status            |                 |                                 |                                 |                                 |         |         |
| Ex-smoker                 | 0.972±0.006     | 0.990±0.006                     | 0.984±0.003                     | 0.908±0.004                     | 0.814±0.005 | 0.794±0.004 |
| Smoker                    | 0.972±0.003     | 0.985±0.003                     | 0.971±0.007                     | 0.891±0.007                     | 0.789±0.011 | 0.749±0.009 |
| p-value                   | .942            | .425                            | .056                            | .023                            | .033     | <.0001   |
| Drinking status           |                 |                                 |                                 |                                 |         |         |
| Not a drinker             | 0.962±0.007     | 0.960±0.007                     | 0.978±0.006                     | 0.905±0.006                     | 0.784±0.006 | 0.762±0.005 |
| Moderate                  | 0.949±0.008     | 0.956±0.008                     | 0.982±0.005                     | 0.896±0.005                     | 0.835±0.007 | 0.817±0.006 |
| Heavy drinker             | 0.978±0.003     | 0.996±0.004                     | 0.984±0.004                     | 0.912±0.004                     | 0.858±0.011 | 0.832±0.010 |
| p-value                   | .001            | <.0001                          | .615                            | .019                            | <.0001    | <.0001   |
| Physical activity/ moderate|                 |                                 |                                 |                                 |         |         |
| <2 days/a week            | 0.968±0.004     | 0.973±0.004                     | 0.981±0.004                     | 0.902±0.004                     | 0.805±0.005 | 0.778±0.005 |
| ≥2 days/a week            | 0.979±0.005     | 1.005±0.004                     | 0.985±0.005                     | 0.913±0.005                     | 0.824±0.007 | 0.810±0.006 |
| p-value                   | .049            | <.0001                          | .546                            | .052                            | .021     | <.0001   |
| Monthly Income            |                 |                                 |                                 |                                 |         |         |
| <3 million won            | 0.964±0.004     | 0.972±0.004                     | 0.980±0.004                     | 0.905±0.005                     | 0.798±0.005 | 0.777±0.005 |
| ≥3 million won            | 0.982±0.004     | 1.003±0.005                     | 0.984±0.004                     | 0.906±0.004                     | 0.845±0.008 | 0.820±0.007 |
| p-value                   | .002            | <.0001                          | .471                            | .857                            | <.0001    | <.0001   |
| Education                 |                 |                                 |                                 |                                 |         |         |
| < high school             | 0.932±0.006     | 0.931±0.005                     | 0.979±0.007                     | 0.914±0.008                     | 0.789±0.004 | 0.772±0.004 |
| ≥ high school             | 0.983±0.003     | 1.001±0.004                     | 0.983±0.004                     | 0.904±0.004                     | 0.878±0.009 | 0.840±0.006 |
| p-value                   | <.0001          | <.0001                          | .625                            | .212                            | <.0001    | <.0001   |

Descriptive Statistics: p values are calculated by analysis of variance (ANOVA): all, p value < 0.05. BMD: bone mineral density (g/cm²)

and menopause (Table 3). In males, drinking consumption, physical activity, income, and education level, and all parameters except smoking had significantly positive effects on BMD (p < 0.05, p < 0.01, p < 0.001). Whereas in the pre-menopausal women, only smoking negatively affected T-femur BMD (p < 0.05), all parameters had positively affected BMD in postmenopausal women (p < 0.05, p < 0.01, p < 0.001), while only smoking negatively affected BMD (p < 0.001). Among these variables, the level of education was the most powerful influencing factor in men or postmenopausal women (T-femur of men, p < 0.001 and L-spine of postmenopausal women, p < 0.001).

In the examination of the metabolic parameters, the ANCOVA test, adjusted for weight, also revealed distinct susceptibility profiles for the three subject groups (Table 4). Among the metabolic parameters, low fasting glucose was found to have a negative association with the T-femur BMD of men, while high HDL negatively affected both BMD parameters in men. WC showed a strong relationship with the L-spine and T-femur BMD in all three subject groups (men, p < 0.001, pre-menopausal women, p < 0.01, post-menopausal women, p < 0.01), and especially for men, but not for the L-spine of pre-menopausal women.
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Table 5 shows different effects of body composition as their relationship between body composition and bone health. We analyzed age, height, TLM, TFM, and WC, except body weight, because TFM plus TLM (muscle mass including bone mass) is generally equal to body weight. Our present study confirmed that the TFM and TLM parameters, when excluding weight from the variables for analysis, could be divided into two categories that would resolve collinearity problem. The results of our analysis excluding body weight are shown in Table 5. The correlation of body composition to BMD is furtherly described. When TFM and TLM, after excluding weight, were used as parameters, the variables showed independent correlations and stabilized variance inflation factors (VIF) values ranging between 1.287 ~ 5.95. Although among these variables has a significant correlation, in case that the VIF values are less than 10, it can be construed as statistically that there is no collinearity. After the exclusion of body weight from the relationship factors,
both TFM and TLM of all women showed positive relationships with BMD (p < 0.001), while the TFM of men did not. In contrast, WCs of men (standardized $\beta = -0.14$, p < 0.01), pre-menopausal women (standardized $\beta = -0.15$, p < 0.001), and post-menopausal women (standardized $\beta = -0.17$, p < 0.001) consistently correlated negatively with BMD in the L-spine and T-femur BMD. We found that both TFM and TLM were interdependently related to BMD. Age and height correlated negatively with BMD in all groups, except for the age of pre-menopausal women positively with the L-spine BMD. The TFM was in the positively correlated to BMD in women. In fact, lean body mass had a powerfully significant association with high BMD in all three groups: (standardized $\beta = 0.68$, in men), (standardized $\beta = 0.52$, in pre-menopausal women), and (standardized $\beta = 0.39$, in post-menopausal women) (p < 0.001).

The relationship between WC quartiles and BMD was confirmed by two BMD parameters by ANCOVA testing. In all three subject groups, a WC increase was correlated with lower BMD, and statistically significant negative relationships were found with T-femur BMD in men and in pre-menopausal women ($R^2 = 0.326$; p < 0.01 and $R^2 = 0.232$; p < 0.01, respectively). Lumbar spine BMD also decreased with WC increase in men and pre-menopausal women ($R^2 = 0.189$; p < 0.05 and $R^2 = 0.181$; p < 0.05, respectively). These data confirm a negative relationship between abdominal obesity and BMD in men and pre-menopausal women, but not significant in postmenopausal women (Figure 1).

Table 5. Results of multiple regression analysis investigating the relationships between bone mineral density (BMD) and general clinical parameters by gender and menopause

|                        | L-spine BMD                      | T-femur BMD                      |
|------------------------|----------------------------------|----------------------------------|
|                        | standardized B | p-value | standardized B | p-value |
| **Men** (n = 2,908)    |                    |        |                |        |
| Age                    | -0.01              | 0.629  | -0.17          | <.0001  |
| Height                 | -0.05              | <0.05  | -0.22          | <.0001  |
| TFM                    | -0.01              | 0.690  | 0.08           | 0.062   |
| TLM                    | 0.47               | <.0001 | 0.68           | <0.001  |
| WC                     | -0.10              | <0.01  | -0.14          | <0.01   |
| **Premenopausal women** (n = 1,987) |                    |        |                |        |
| Age                    | 0.05               | <.0001 | -0.02          | 0.716   |
| Height                 | -0.08              | <.0001 | -0.23          | <.0001  |
| TFM                    | 0.16               | <.0001 | 0.22           | <.0001  |
| TLM                    | 0.42               | <.0001 | 0.52           | <.0001  |
| WC                     | -0.12              | <0.01  | -0.15          | <.0001  |
| **Postmenopausal women** (n = 1,438) |                    |        |                |        |
| Age                    | -0.31              | <.0001 | -5.81          | <.0001  |
| Height                 | -0.04              | 0.193  | -2.33          | <.0001  |
| TFM                    | 0.28               | <.0001 | 5.73           | <.0001  |
| TLM                    | 0.28               | <.0001 | 10.49          | <.0001  |
| WC                     | -0.17              | <.0001 | -2.39          | <.0001  |

B denotes the standardized regression coefficients. TFM: total fat mass (kg); TLM: total lean mass (kg); WC: waist circumference (cm)
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Table 6. Multiple regression analysis for two models that investigate the relationship between abdominal obesity (WC) and bone mineral density (BMD), after controlling for other variables by gender and menopausal status.

| Abdominal Obesity | L-spine BMD | | | T-femur BMD | | |
|-------------------|-------------|----------------|----------------|----------------|
|                   | B           | Std β          | p-value         | B           | Std β          | p-value         |
| **Men (n = 2,908)** |             |                 |                 |             |                 |                 |
| Model I           | -22.56      | -0.075         | <0.01           | -24.95      | -0.127         | <.0001          |
| Model II          | -29.84      | -0.070         | <.0001          | -32.15      | -0.111         | <.0001          |
| **Premenopausal women (n = 1,987)** |             |                 |                 |             |                 |                 |
| Model I           | -20.48      | -0.050         | 0.080           | -30.50      | -0.092         | <0.01           |
| Model II          | -21.32      | -0.052         | 0.068           | -32.26      | -0.097         | <.0001          |
| **Postmenopausal women (n = 1,438)** |             |                 |                 |             |                 |                 |
| Model I           | -15.00      | -0.040         | 0.106           | -13.11      | -0.043         | 0.102           |
| Model II          | -8.69       | -0.013         | 0.324           | -9.62       | 0.030          | 0.191           |

Note: Std β = Standardized beta. B denotes the regression coefficients.
Model I: Adjusted for age, weight, and height. Model II: Adjusted for all parameters of Model I plus variables, with significant effects for each group shown in Table 3 and Table 4: Smoking, drinking habits, physical activity, income, education, impaired fasting glucose (mg/dL), high-density lipoprotein (mg/dL).

The effect of gender and menopause on the effects of abdominal obesity in relation to changes in BMD was tested using two complexity models. While these two models of abdominal obesity in men were predictive of a negative relationship both with spinal and femoral BMD (Table 6) (standardized β = -0.070, p < 0.0001 and standardized β = -0.111, p < 0.0001, respectively), in pre-menopausal women, they predicted a negative relationship only with femoral BMD (standardized β = -0.097, P < 0.0001).

In contrast, relationships between any of these models and BMD were not predictive in postmenopausal women. By this study, we established a strong negative relationship of the abdominal obesity and BMD of men, whereas the predictive value is limited for women in the Korean population. At this study, adjustments for age, weight, and height were done in Model 1; while in the case of men, adjustments were done in Model II for drinking, physical activity, income, education, impaired fasting glucose, and HDL-cholesterol, but smoking was excluded from men’s adjustment variables. In the case of pre-menopausal women, adjustments for smoking, while in the case of post-menopausal women, adjustments for smoking, drinking, physical activity, income, education. As for metabolic parameters, they were all excluded from adjustment in women. Among the variables, the level of education was powerful influencing factors in men or post-menopausal women.
4. Discussion

Analysis of the KNHANES IV database provides a unique opportunity to identify gender-specific relationships for osteoporosis using a large number of demographic, social, and clinical variables. This present study established that BMD and WC are negatively correlated to each other in all the groups of men, pre-menopausal and post-menopausal women. Multivariate analysis revealed the relationship of BMD with abdominal obesity is considerably with effects of gender and menopause after control about the nuisance factors. This allowed us to test the predictive of two models of abdominal obesity with respect to bone loss in three subject groups.

4.1 Socio-Economic Factors Affecting BMD

We can explain why osteoporosis in women is more prevalent than in men >50 years by the socio-cultural context in Korea. The income, physical activity, and higher education were analyzed to all have positive association with the preventive of osteoporosis both in men and post-menopausal women; while smoking to have negative association in all women regardless of their menopause. In this result are consistent with an earlier study that showed socioeconomic position has a positive relationship with BMD in the Korean population, but specifically for men and postmenopausal women. Exercise has known benefits for bone morphometry; while smoking, on the other hand, has negative effects not only on the quality of life but also the total mortality of more than middle-aged women. Increased knowledge about healthy lifestyle choices, and, therefore, healthier behaviors of post-menopausal women may result in the positive effects on bone health - as recently found in a study on Chinese women. In the present study, the relationship of drinking habits of Korea people to bone health did not conform to the general knowledge that drinking has a negative influence on bone health; it was shown to positively affect it. Many types of researches regarding the relationship of drinking and bone density have indicated that drinking has adverse effects on bone density. Therefore, the existing contribution suggests a strong need for active research into this matter.

4.2 WC and BMD

In this study, a WC indicated that abdominal obesity had a relationship with BMD, independently of TFM. We found that women experienced an increase in WC after menopause, at which point their WC values became equivalent to those measured in men. WC was also discovered to correlate to BMD negatively with statistical significance in all three subject groups. This is likely due to the insulin resistance caused by low estrogen production during menopause in women. In, also, reported that bone losses due to the underlying indirect causes including hypogonadism and steroids, from which more than 50% of men with symptomatic vertebral crush fracture are likely to suffer, may speed up the progress of osteoporosis.

Furthermore, the risk of vertebral fractures increases when elderly men have the behavior of smoking or alcohol use, and baseline secondary causes of osteoporosis. In addition, visceral obesity is related to dysregulated hormones that are important regulators of bone homeostasis. Cumulatively, these results provide some strong support for the hypothesis that visceral fat mass has detrimental effects on BMD.

4.2 TFM and BMD

We found that relationships between TFM and BMD varied according to gender and time since menopause onset. The relationship with TFM and BMD was notable in women. Our results support those of previous studies in which TFM and BMD were negatively correlated in men, but not in women. Especially, these findings support those, who reported negative correlations between TFM and BMC after removing the mechanical loading effect. According to, the main drivers of bone loss of postmenopausal women are duration between the physiological age from menopause, although body weight, height, and bone mass index can also influence bone loss. During the early postmenopausal stage, women were also observed to undergo accelerated bone loss.

4.3 TLM and BMD

TLM improves BMD because both muscle and bone size can be increased by exercise; this is a result of the mechanical loading effect of weight. Of all the variables measured here, indeed, we found that TLM, unlike WC, had a positive relationship with BMD in all groups. These data support previous findings indicating that TLM makes a positive impact on the human body involved both sex.
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4.4 Interaction between TLM and TFM

TFM and TLM are interdependently related with BMD; this is particularly true in elderly women. In men, soft tissue appears to be relatively less important; rather, the overall size of the skeleton is more central to the effect of muscle mass on bone metabolism. In reported that body size and BMD are associated with each other in both sexes; furthermore, BMD in the weight-bearing area was higher compared to that of the non-weight-bearing area, which again emphasizes the importance of mechanical effects of weight on BMD. Both TFM and TLM probably contribute to the effect of overall body weight, and the first of these two variables has been more consistently linked with BMD, especially in women. However argued TFM adjusted for body weight can be confusing due to the common linear trend between the research variables. In our analysis, due to the collinearity problem among the key variables, weight was excluded from analysis by accounting for bivariate correlations among all of the key variables. The problem of collinearity was checked by adding variance inflation factor values, and all the key variables changed stably and independently, respectively.

In the study of body composition, using TFM and TLM with weight typically may be confusing. For weight is generally equal to TFM plus TLM (muscle mass including bone mass). These studies confirm that there still remain a controversy over the issue of that fat and lean mass indeed give the effects on bone metabolism. Therefore, more studies have analyzed abdominal obesity or partial fat after adjusting for weight bearing recently. Our present study confirms that the TFM and TLM parameters, when excluding weight from the variables for analysis, could be divided into two categories that would resolve collinearity problem. The results of our analysis excluding body weight are shown in Table 5. The correlation of body composition to BMD was explained in detail.

The main mediators of the fat mass are likely to be the environmental influences. The increases in LM and physical activity may be directly protective for osteoporosis. On the other hand, if BMD is associated with FM, adjusting for eating habits could give a similar impact. These discrepancies may be attributed to confounding problems of statistical and genetic factors. Since lean mass and fat mass are necessarily associated, when handling them as independent elements in a multiple linear regression analysis, it isn’t easy to tell the specific effect of each component from another. However, this collinearity problem is not to be solved by the statistical model, but it can partially controlled in the phase of study design.

Accordingly, results suggest that these conflicts can be a complex effect on BMD of TFM, and at least in part, due to a lack of covariates related research including gender, sample size, and race, as well as research design and analytical techniques. Therefore, additional research is needed to expand the current knowledge about the relationship of fat tissue and bone health. Differences in gender and changes in hormones due to menopause have a different effect on the interaction of TFM and TLM in these particular women. In the present study, however, TLM (total muscle mass) is considered to play a more important role in bones than does TFM. This implies that increasing muscle and decreasing excessive TFM through regular exercise can prevent abdominal obesity and keep the bones healthy.

4.5 Model Analysis

The present study demonstrated that high waist circumference has a negative influence on bone metabolism. However, abdominal obesity has a different effect that varies according to gender and menopausal status when the diagnostic criteria of abdominal obesity using WC are reclassified and adjusted as diverse covariates that affected bone health in male, pre-menopausal, and post-menopausal female groups. Furthermore, abdominal obesity has a different distribution of fat according to age, sex, and hormonal conditions. While excess storage of visceral fat increases with age in men, this process worsens after menopause in women.

4.6 Strengths and Limitations of Current Study

This study indicates several key points of strengths. First, to the best of our knowledge, this study may be the first case that has examined the relationship between abdominal obesity and BMD among Korean adults including men, pre-menopausal women and post-menopausal women using data collected from around the country. Second, by including a large number of demographic, social, and clinical variables, we were able to control for as many covariates as possible known to affect BMD. Third, we were able to test the predictive power of two different models of abdominal obesity with respect to bone loss in three different types of participants.
However, this study also has a few limitations. First, due to the characteristics of a cross-sectional design of this study, the results only tells about associations but not the causality between abdominal obesity and a decrease in BMD. Second, we used WC as an indicator of abdominal obesity, rather than quantitatively measuring the adipose tissue in subcutaneous and visceral area. WCs may underestimate visceral obesity; furthermore, the ability of WC to predict intra-abdominal fat may vary depending on the subject age. However, WC alone can predict clearly the intra-abdominal fat volume or area, which is likely to be predictive of health risk. Third, these discrepancies could be attributed to differences of different research such as in the method of measurement, the skeletal site of measuring the bone mass as well as the genetic background, lifestyle, living environments of target populations.

5. Conclusion

Our models suggest that abdominal obesity of Korean men and pre-menopausal women is negatively related to BMD and a narrow waist and lean body weight favor high BMD. On the other hand, in post-menopausal women, abdominal obesity was not shown to have a negative correlation to BMD. Based on these findings, we suggest that preventive programs should be recommended separately for each group of men, pre-menopausal and post-menopausal women in Korea.

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