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Abdominal Obesity is Associated With *Lower* Bone Mineral Density in Non-Weight-Bearing Site in Korean Men

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Abstract

This research aimed to investigate the relationship between abdominal obesity and *lower* bone mineral density (BMD) at non-weight-bearing site in Korean men using data from the Korea National Health and Nutrition Examination Survey, which is a nationwide cross-sectional survey. The study population (n = 5,941) was selected from the 2009–2010 survey. Abdominal obesity in men was defined as waist circumference ⩾ 90 cm. *Lower* BMD state was defined as having T-score of −2.5 or below. To investigate the association, multiple logistic regression analysis was performed. Abdominal obesity was highly associated with *lower* non-weight-bearing site (lumbar spine [LS]) BMD after adjustment (odds ratio [OR] 1.61, 95% CI [1.06, 2.44], p = .026). Also, abdominal obesity was a risk factor for *lower* LS BMD, especially in age groups of those in their 20s and those over 60s (OR 5.53, 95% CI [1.27, 24.07], p = .023 for 20s; OR 2.19, 95% CI [1.19, 4.02], p = .011 for 60 years or older). Abdominal obesity in Korean men is associated with *lower* BMD at non-weight-bearing site (LS), especially in younger and older age groups. Further research might be recommended to prove the mechanism or causality.

Keywords

abdominal obesity, bone mineral density, non-weight-bearing site, Korean men

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The prevalence of obesity has increased dramatically worldwide over the past decade. Abdominal obesity, potentially through greater visceral fat, is an important risk factor for cardiovascular and metabolic complications (Janssen, Katzmarzyk, & Ross, 2002). Researchers have increasingly studied abdominal obesity owing to its potential significant impact on a variety of health outcomes. Recently, abdominal obesity has been considered to be a more important independent risk factor for disease than general obesity in Koreans (Park, Yun, Park, Kim, & Choi, 2003). The criterion for abdominal obesity is having a waist circumference (WC) 90 cm (35.4 in.) or more in men or 85 cm (33.5 in.) or more in women (Lee et al., 2007). According to the Korea National Health and Nutrition Examination Survey (KNHANES), the incidence of male abdominal obesity was 19.1% in 2010.

Osteoporosis is characterized by *lower* bone mineral density (BMD). Osteoporosis is a potential risk factor for pathologic fracture. A predictable course of pathologic fracture may include decreased activities of daily living and increased comorbidities. Some studies have reported that smoking, alcohol, and menopause in women are risk factors for osteoporosis that can be managed clinically (Ebeling, 2008; Guadalupe-Grau, Fuentes, Guerra, & Calbet, 2009). Interestingly, obesity or weight gain has been considered protective against the development of bone loss and osteoporosis, with the potential role of mechanical loading in regulating bone remodeling (Albala et al., 1996; Felson, Zhang, Hannan, & Anderson, 1993). However, studies on abdominal obesity and osteoporosis in men are limited.

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Osteoporosis continues to be an underrecognized problem in men. It also goes untreated in the majority of men with fractures (Ebeling, 2008).

WC is frequently used as a simple and inexpensive measure of abdominal obesity. Abdominal obesity is robustly associated with diabetes mellitus, hyperlipidemia, certain cancers, and cardiovascular disease (Ramachandran & Snehalatha, 2010). However, it may be a challenge to study abdominal obesity as it relates to other metabolic complications. Some studies have suggested that body composition of fat and muscle may affect BMD (Bleicher et al., 2011). Other studies regarding the association between WC and BMD have been inconsistent (Kinjo, Setoguchi, & Solomon, 2007). The objective of the present study was to determine the association between abdominal obesity using WC and *lower* BMD in men after adjusting for confounders using data from the KNHANES.

Method

Study Population

This study analyzed KNHANES data from 2009 to 2010 (2 years). KNHANES is a nationwide cross-sectional survey to assess the health and nutritional status of Koreans since 1998 (Kweon et al., 2014). Based on the National Health Promotion Act, these surveys have been conducted by the Korea Centers for Disease Control and Prevention (KCDC). The dataset had 18,552 subjects in total (8,451 men). Subjects who reported a history of thyroid disease or osteoporosis therapy or were under 19 years old were excluded. In total, 5,941 male subjects were included in the analysis. According to the criteria for abdominal obesity for Korean adult men (WC $\geqslant$ 90 cm; 35.4 in.), subjects were divided into two groups: 4,430 in the normal group (reference) and 1,511 in the abdominal obesity group.

General Characteristics

Trained interviewers administered a structured questionnaire and anthropometric measurements. Medical history, social history, and lifestyle habits were collected using self-reported questionnaires. Smoking history was categorized into current smoker and nonsmoker (including ex-smoker) groups. Doing exercise was defined as strenuous physical activity performed for a minimum of 30 min, once a week, using the questionnaire. Alcohol intake issues were assessed using the Alcohol Use Disorders Identification Test (AUDIT) score (Smith, Schmidt, Allensworth-Davies, & Saitz, 2009). Interviewers recorded calcium and phosphate intake using a multiple-pass 24-hr dietary recall questionnaire. Dietary nutrient intake was estimated from items included in the food composition table.

Anthropometric measurements for each participant were taken with light clothing on and no shoes. Height was measured to the nearest 0.1 cm. Weight was measured with a metric weight scale to the nearest 0.01 kg. BMI was calculated as weight divided by square of the body height (kg/m^2). WC was measured as the midpoint between the lower border of rib cage and the highest point of the iliac crest of the subject with a tape measurement (Seca 200, Seca, Germany, max 200 cm) to the nearest 0.1 cm at the end of normal expiration.

A laboratory test including vitamin D was administered in the morning after at least 10 hr of fasting. All biochemical markers were analyzed on the same day. Vitamin D (serum 25-hydroxyvitamin D) was measured using a 1470 WIZARD Gamma Counter (PerkinElmer Inc., Turku, Finland) with a 25-hydroxyvitamin D1251 RIA Kit (DiaSorin Inc., Stillwater, MN).

BMD Measurement

BMD was measured using dual-energy X-ray absorptiometry (DEXA; Hologic Discovery-W; Hologic, Bedford, MA). Total femur, femoral neck, and lumbar spine (LS) BMDs were measured. L1–L4 values were chosen for the LS BMD analysis (Yang & Kim, 2014). *Lower* BMD was defined as T-score $\leqslant -2.5$ in any site according to the World Health Organization (WHO) T-score criteria calculated with a reference for Asian men. In this study, considering a weight-protective effect on BMD, osteoporosis was divided into two categories: (a) the LS, reflecting the non-weight-bearing site and (b) the femur neck and total femur, reflecting the weight-bearing site.

Ethical Approval and Informed Consent

All procedures performed in studies involving human subjects were in accordance with the ethical standards of the institutional and/or national research committee and the tenets of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all subjects included in the study. The Research Ethics Review Committee of the KCDC approved the raw data from the KNHANES used in this study (KNHANES IV-3, V-1). Prior to the commencement of this research, the research protocol was approved by the Institutional Review Board of the Catholic University of Korea, Seoul St. Mary's Hospital (IRB approval number: KC15QISI0755).

Statistical Analysis

All statistical analyses were performed using SAS software version 9.3 (SAS Institute Inc., Cary, NC). The

Table 1. Basic Characteristics of Total Study Population.

Total $n = 5{,}941$ ($N = 18{,}632{,}328$)

	Lumbar spine T-score			
	T-score $\leqslant -2.5$	$-2.5 <$ T-score $\leqslant -1.0$	$-1.0 <$ T-score	
n (weighted %)	573 (8.4%)	1,664 (26.1%)	3,704 (65.5%)	*p**
Mean ± SE				
Age (years)	49.7 ± 1.0	46.6 ± 0.5	42.1 ± 0.4	<.001
BMI (kg/m^2)	22.7 ± 0.2	23.2 ± 0.1	24.5 ± 0.1	<.001
Waist circumference (cm)	81.1 ± 0.5	82.1 ± 0.3	84.9 ± 0.2	<.001
AUDIT	9.2 ± 0.4	9.8 ± 0.2	10.2 ± 0.1	*<.001*
Vitamin D level (nmol/L)	18.7 ± 0.5	18.7 ± 0.3	18.9 ± 0.2	*.584*
Calcium intake (mg/day)	536.9 ± 25.7	568.9 ± 12.0	588.9 ± 7.4	*<.001*
Phosphate intake (mg/day)	1248.5 ± 36.4	1342.6 ± 19.1	1426.3 ± 11.8	<.001
n (weighted %)				
Doing exercise[a]	152 (34.4%)	598 (40.5%)	1,679 (49.8%)	<.001
Current smoker	245 (50.9%)	694 (47.3%)	1,601 (47.7%)	<.001

Note. AUDIT = Alcohol Use Disorders Identification Test; BMI = body mass index; SE = standard error.
[a]Doing exercise factor was defined as strenuous physical activity performed for a minimum 30 min once a week.
*Kruskal–Wallis tests were used for numeric variables and χ^2 tests were used for categorical variables.

sampling weights for each sample were the products of three factors: the reciprocal of the probabilities of selection (primary sampling unit [psu]; household); an adjustment for nonresponse (household, person); and a post-stratification factor to make the resulting survey estimates for age, sex, metropolitan area, or province category approximately equal to the total population of Korea (Kim, 2014).

To *present* the characteristics of the study subjects, subjects were divided into the following three groups by LS T-score: T-score $\leqslant -2.5$, $-2.5 <$ T-score $\leqslant -1.0$, and $-1.0 <$ T-score. Numeric values were described by mean values and standard errors (SEs). Categorical values were described by number with a weighted percentage. To compare variables among the three groups (T-score $\leqslant -2.5$, $-2.5 <$ T-score $\leqslant -1.0$, and $-1.0 <$ T-score), Kruskal–Wallis tests for numeric variables and χ^2 tests for categorical variables were performed. Subjects were divided into a normal group (WC $<$ 90 cm; 35.4 in.) and an abdominal obesity group (WC $\geqslant$ 90 cm; 35.4 in.) to calculate odds ratios (ORs). Mann–Whitney tests were used for continuous variables and χ^2 tests were used for categorical variables to compare between the abdominal obesity and normal groups. Two-sided $p < .05$ was considered statistically significant. At this stage, potential confounders were determined.

To clarify ORs, multiple logistic regression was used. ORs were calculated in three ways (Models 1, 2, and 3). Model 1 was unadjusted value. To account for the effects of anthropometric variables, age and BMI were adjusted in Model 2. In Model 3, potential confounders such as age, BMI, AUDIT score, vitamin D level, and doing exercise were adjusted. Also, ORs were analyzed among age groups by 10 years. For each group, multiple logistic regression was used to calculate ORs between abdominal obesity and osteoporosis.

Results

Among 5,941 subjects (estimated population $N = 18{,}632{,}328$) from the KNHANES 2009–2010 data, 573 (8.4%) were in *lower* BMD state. The baseline characteristics of subjects divided into three groups (T-score $\leqslant -2.5$, $-2.5 <$ T-score $\leqslant -1.0$, and $-1.0 <$ T-score) are presented in Table 1. In the first group (T-score $\leqslant -2.5$), the mean age was 49.7 ± 1.0 years and the mean WC was 81.1 ± 0.5 cm (31.9 ± 0.2 in.). Mean calcium intake (536.9 ± 25.7 mg/day) was lower than 700 mg/day, which is recommended for Korean male adults by the Korean Nutrition Society (Society, 2015). *Only vitamin D level in numerical variables was not different among the three groups ($p = .584$).* The exercise factor was significantly different among the three groups (34.4%, 40.5%, and 49.8%, respectively; $p < .001$).

The basic characteristics of the two main groups by WC (abdominal obesity and normal groups) are reported in Table 2. In the abdominal obesity group ($n = 1{,}511$), the mean WC was 95.7 ± 0.2 cm (37.6 ± 2.2 in.). Age ($p < .001$), BMI ($p < .001$), AUDIT ($p = .007$), vitamin D level ($p = .003$), and doing exercise ($p = .010$) were significantly different between the two groups.

Table 2. Basic Characteristics of Abdominal Obesity and Normal Groups.

Total n = 5,941 (N = 18,632,328)			
	Abdominal obesity[b]	Normal	
n (weighted %)	1,511 (24.0%)	4,430 (76.0%)	p*
Mean ± SE			
Waist circumference (cm)	95.7 ± 0.2	80.1 ± 0.1	
Age (years)	46.7 ± 0.4	43.0 ± 0.4	<.001
BMI (kg/m^2)	27.6 ± 0.1	22.9 ± 0.1	<.001
AUDIT	10.6 ± 0.3	9.8 ± 0.2	*.006*
Vitamin D level (nmol/L)	19.4 ± 0.3	18.7 ± 0.2	*.032*
Calcium intake (mg/day)	598.1 ± 12.6	573.5 ± 6.7	*.060*
Phosphate intake (mg/day)	1409.4 ± 20.0	1384.0 ± 13.0	*.170*
n (weighted %)			
Doing exercise[a]	581 (42.6%)	1,848 (47.3%)	.010
Current smoker	605 (46.2%)	1,935 (48.3%)	.239

Note. AUDIT = Alcohol Use Disorders Identification Test; BMI = body mass index; SE = standard error.
[a]Doing exercise factor was defined as strenuous physical activity performed for a minimum 30 min once a week. [b]Abdominal obesity was defined as having a waist circumference 90 cm or above in men.
*Mann–Whitney tests were used for numeric variables and χ^2 tests were used for categorical variables.

The ORs of *lower* BMD at non-weight-bearing site due to abdominal obesity are reported in Table 3. The ORs of Models 2 and 3 in *lower* LS BMD were statistically significant (Model 2, OR: 1.56, 95% CI [1.09, 2.25], p = .017; Model 3, OR: 1.61, 95% CI [1.06, 2.44], p = .026). The ORs in other two weight-bearing sites were not statistically significant.

The ORs stratified by age for *lower* LS BMD are reported in Table 4. In the 20s group (n = 794), abdominal obesity was significantly associated with osteoporosis (Model 3, OR: 5.53, 95% CI [1.27, 24.07], p = .023). The analyses included 1,124 subjects for the 30s group, 1,175 for the 40s group, and 1,015 for the 50s group. There was no statistically significant association between abdominal obesity and osteoporosis in these three groups. Abdominal obesity was also significantly associated with osteoporosis in the 60 years or older group (n = 1,833; Model 3, OR: 2.19, 95% CI [1.19, 4.02], p = .011). The analysis displayed a biphasic pattern for age categories.

Discussion

This study is the first to determine the association between abdominal obesity and osteoporosis in Korean adult men. Data used in this study were based on a representative government-sponsored survey in South Korea. Using this national data, abdominal obesity was reported to be significantly associated with *lower* BMD at non-weight-bearing site in adult men after adjusting potential confounders (OR = 1.61). After adjusting potential confounders, the study reported that abdominal obesity was no longer a significant factor for BMD *lower* at weight-bearing sites. This may be due to the potential protective effect of increased body weight. Increased body weight may protect BMD from decreasing, according to previous research (Albala et al., 1996; Felson et al., 1993). Despite the potential positive effect of increased body weight on BMD, abdominal obesity may be more critical at non-weight-bearing sites than at weight-bearing sites. According to this result, it can be assumed that the positive effect of body weight on BMD at non-weight-bearing sites would be overwhelmed by the negative effect of abdominal obesity. It can be inferred that some adipokine from abdominal or visceral fat tissue can influence the mechanism of this, offsetting the *lower* BMD in the non-weight-bearing site. Some evidence to support this hypothesis is put forward in the next paragraph. Additional research in this area can be considered.

In age group analysis, a biphasic pattern was identified in the 20 years group and the 60 years and older group. The risk association between abdominal obesity and *lower* LS BMD was increased in the 20s group with a wide confidence interval. These results were related to mechanisms of dynamic bone metabolism and visceral fat adipocyte metabolism, such as the obesity paradox mechanism (Dimitri, Bishop, Walsh, & Eastell, 2012; Janicka et al., 2007; Nishimura, Hata, & Yoneda, 2007). First, BMD increases and maintains its peak density in younger age groups, such as the 20s. At younger ages, dynamic metabolism can occur in the bone marrow. Some studies have reported a relationship between osteoblasts and adipocytes through mesenchymal stem cells (MSCs;

Table 3. Associations Between Abdominal Obesity and Body Weight–Related Site Bone Loss.

T-score ⩽ −2.5

	Abdominal obesity[a]		
	OR	95% CI	*p*
Non-weight-bearing site			
Lumbar spine			
Model 1	0.33	[0.27, 0.41]	<.001
Model 2	1.56	[1.09, 2.25]	.017
Model 3	1.61	[1.06, 2.44]	.026
Weight-bearing site			
Femur neck			
Model 1	0.55	[0.40, 0.76]	<.001
Model 2	1.20	[0.76, 1.88]	.428
Model 3	1.09	[0.65, 1.82]	.755
Total femur			
Model 1	0.62	[0.42, 0.92]	.017
Model 2	1.09	[0.62, 1.92]	.754
Model 3	0.89	[0.47, 1.68]	.723

Note. Multiple logistic regression was used. Reference group was defined as having a waist circumference under 90 cm. Model 1 was unadjusted. Model 2 was adjusted for age and body mass index. Model 3 was adjusted for age, body mass index, alcohol use disorder identification test score, vitamin D level, and doing exercise. 95% CI = 95% confidence interval; OR = odds ratio.
[a]Abdominal obesity was defined as having a waist circumference 90 cm or above.

Table 4. Associations Between Abdominal Obesity and Lumbar Spine Bone Loss by Different Age Groups.

Lumbar spine T-score ⩽ −2.5

			Abdominal obesity[a]		
Age group[b]			OR	95% CI	*p*
	n (weighted %)				
20s	794 (20.8%)	Model 1	1.00	[0.43, 2.32]	.993
		Model 2	8.79	[2.29, 33.69]	.002
		Model 3	5.53	[1.27, 24.07]	.023
30s	1,124 (22.4%)	Model 1	0.46	[0.21, 1.01]	.054
		Model 2	0.85	[0.34, 2.15]	.731
		Model 3	1.26	[0.43, 3.73]	.678
40s	1,175 (22.6%)	Model 1	0.74	[0.40, 1.40]	.353
		Model 2	1.42	[0.58, 3.48]	.444
		Model 3	1.18	[0.44, 3.12]	.745
50s	1,015 (17.3%)	Model 1	0.60	[0.32, 1.10]	.098
		Model 2	1.04	[0.52, 2.06]	.268
		Model 3	1.12	[0.55, 2.30]	.758
60s or more	1,833 (17.0%)	Model 1	0.59	[0.39, 0.89]	.012
		Model 2	1.66	[1.00, 2.74]	.048
		Model 3	2.19	[1.19, 4.02]	.011

Note. Multiple logistic regression was used. Reference group was defined as having a waist circumference under 90 cm. Model 1 was unadjusted. Model 2 was adjusted for age and body mass index. Model 3 was adjusted for age, body mass index, alcohol use disorder identification test score, vitamin D level, and doing exercise. 95% CI = 95% confidence interval; OR = odds ratio.
[a]Abdominal obesity was defined as having a waist circumference over 90 cm or above.
[b]Study subjects were categorized by 10 years into five groups: 20s, 30s, 40s, 50s, and 60s or more.

Chiellini et al., 2008). Pluripotential MSCs are common progenitors with the ability to be differentiated equally into various cell lineages (Akune et al., 2004; Gregoire, Smas, & Sul, 1998). Cytokines from subcutaneous or visceral fat tissue such as IL-6, leptin, and adiponectin will change the mechanism of differentiation (Rosen & Bouxsein, 2006). By such processes, MSCs in bone are changed to adipocytes rather than osteoblasts. As a result, abdominal obesity due to excess visceral fat tissue may serve as a risk factor for decreasing bone density since in younger age groups (20s), active osteoblasts promote anabolic bone metabolism. This dynamic metabolic effect can explain the wide range of ORs in the 20s group. Second, recent evidence has demonstrated that truncal fat mass is associated with lower trabecular bone volume and a tendency to develop osteoporosis (Cohen et al., 2013). Osteoporosis in men is due to bone loss from trabecular thinning secondary to reduced bone formation (Khosla et al., 2006). Truncal fat tissue may affect osteoblast activity related to bone resorption and formation through RUNX family genes (Komori, 2011). This hypothesis also explains why abdominal obesity may be associated with *lower* BMD in younger age groups (20s) when osteoblasts are active. Third, changes in the insulin-like growth factor 1 (IGF-1) regulation system may result in trabecular bone loss in young men (Riggs et al., 2008). Visceral fat tissue disturbs metabolism related to IGF-1 in the same manner that visceral fat tissue increases metabolic diseases such as diabetes mellitus. Fourth, studies have revealed that after 70 years of age, male bone loss is accelerated (Szulc & Delmas, 2001). Reductions in male sex hormones, such as testosterone, may result in decreases in bone density. In association with decreased testosterone activity, cortical bone loss and bone remodeling increase in older age, especially over 50 years of age (Riggs et al., 2008).

This study has the following limitations as well as the limitations already mentioned. First, the exclusion criteria did not consider including the use of glucocorticoids. Steroid agents are known to be the most important factor causing *lower* BMD. Second, there is a limit to acquired information in KNHANES. Abdominal obesity using WC was limited to imply that abdominal obesity may be an indicator of visceral or subcutaneous fat distribution. Additional rigorous studies using abdominal fat computed tomography or other body composition analysis tools may further clarify this issue. Some information dependent on memory recall was easy to be distorted and to be exposed to recall bias. Especially, using only 24-hr recall is a poor reflection of calcium and phosphate intake, although it is understandable that it is not feasible to record longer periods. Potentially useful data to approve the analysis was omitted due to a standardized and fixed questionnaire. Estimates of vitamin D levels may have changed depending on seasons. There was a limit to analyzing such variations because laboratory tests were completed only once. Third, WHO criteria for Asian people (T-score $\leqslant -2.5$) was used to define *lower* BMD, not osteoporosis. Using T-score cannot define osteoporosis in young age under 50 years. Some studies suggested that a Z-score should be used for young adults. Young adult osteoporosis can be considered in terms of low bone density with skeletal fragility evidence. Further studies using T-scores for young adults may be necessary. Fourth, statistical analysis using only data from Korean population may limit generalizability across other populations; further molecular and epidemiological studies are needed. Finally, this research is a cross-sectional study that cannot predict the causality. The outcome above implies the association, not the risk factor. This implication may suggest the direction of further studies about the association between adult men's lower BMD and osteoporosis.

Conclusion

In this study, abdominal obesity was identified to be a risk factor for non-weight-bearing osteoporosis, especially in young men and those 60 years of age and older. Moreover, young men should attend to abdominal obesity at an early age owing to its age-related association. Further studies concerning mechanisms about the effect of abdominal obesity on BMD should be conducted for clarification.

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