

Association between body mass index and fragility fracture in postmenopausal women: a cross-sectional study using Korean National Health and Nutrition Examination Survey 2008-2009 (KNHANES IV)

Jihan Kim

Sejong Trinium Woman's Hospital

Sami Lee (✉ smlee@cnuh.co.kr)

Chungnam National University Hospital

Sung Soo Kim

Chungnam National University Hospital

Jong-Pyo Lee

Sejong Trinium Woman's Hospital

Jong Sung Kim

Chungnam National University Hospital

Jin Gyu Jung

Chungnam National University Hospital

Seok Jun Yoon

Chungnam National University Hospital

Kyu Pil Kim

Chungnam national university Sejong hospital

Chan-Keol Park

Chungnam national university Sejong hospital

Yong-Hwan Kim

Chungnam National University Hospital

Research article

Keywords: Osteoporotic fractures, Body Mass Index, Obestiy, Osteoporosis, Postmenopausal

Posted Date: July 2nd, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-38752/v1>

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 February 9th, 2021. See the published version at <https://doi.org/10.1186/s12905-021-01209-4>.

Abstract

Background: The present study examined the relationship between body mass index (BMI) and the risk for fragility fractures in postmenopausal Korean women.

Method: Among subjects who participated in the 4th National Health and Nutrition Examination Survey (2008-2009), 2114 women ≥ 40 years of age were included. BMI was based on standards set by the Korean Society for the Study of Obesity, as follows: $<18.5 \text{ kg/m}^2$, underweight; $18.5 \leq$ to $<25 \text{ kg/m}^2$, normal weight; and $\geq 25 \text{ kg/m}^2$, obese. Subjects were also divided into three groups according to the location of fragility fracture: spine, hip, or wrist.

Results: The mean (\pm SD) rate of fragility fracture was significantly different among the three groups: $5.9 \pm 2.9\%$ (underweight), $1.1 \pm 0.3\%$ (normal weight), and $3.0 \pm 0.7\%$ (obese) ($p=0.001$). After correcting for age, family history, and treatment history of osteoporosis and rheumatoid arthritis, smoking and drinking status, and level of exercise, multivariable regression analysis revealed that the odds ratio for fragility fracture in the underweight group was 5.51 (95% confidence interval [CI] 1.88–16.13) and 3.19 (95% CI 1.51–6.74) in the obese group. After subdividing fragility fractures into vertebral and non-vertebral, the odds ratio for vertebral fracture in the underweight group was 6.05 (95% CI 1.61–22.68) times higher than that in the normal weight group; in the obese group, the non-vertebral fracture odds ratio was 3.73 (95% CI 1.33–10.44) times higher. Analysis of non-vertebral fractures in the obese group revealed an odds ratio for fracture 8.29 (95% CI 1.04–66.37) times higher for hip fracture and 3.73 (95% CI 1.21–11.43) times higher for wrist fracture.

Conclusions: Obesity and underweight increased the risk for fragility fractures in postmenopausal Korean women. As such, it is important for this patient population to maintain bone health through proper weight management, sufficient exercise, and regular examination of bone density.

Background

Osteoporosis is a musculoskeletal disorder characterized by a decrease in bone density and abnormal changes in bone microstructure.⁽¹⁾ It is one of the most common diseases in postmenopausal women due to the age-related reduction in estrogen levels. Individuals with osteoporosis have a higher risk for fragility fractures due to reduced bone density, and increased risk for resulting complications and mortality rates.⁽²⁾ Fragility fracture refers to a non-traumatic fracture and, according to the World Health Organization (WHO), is defined as a fracture caused by a fall from a level below one's height, including fracture(s) caused by impact that do not cause fracture(s) in normal bones, and even when that impact is not recognized.⁽³⁾ In Korea, women > 50 (59.5%) are more likely to experience fragility fractures in their lifetime than men > 50 (23.8%) years of age.⁽⁴⁾ Therefore, in Korea, the National Health Examination Program, under the aegis of the National Health Insurance Service, was designed for women aged 54 and 66 to undergo testing for bone density in the lumbar spine to diagnose, treat, and manage diseases related to osteoporosis.

One of the most common changes experienced by postmenopausal women is weight gain. Compared with premenopause, postmenopausal women exhibit a 20% increase in fat mass, especially in central adiposity.⁽⁵⁾ In general, it is common for postmenopausal women to exhibit a decrease in bone density with age; however, weight gain has been reported to help maintain bone density.⁽⁶⁾ Therefore, weight loss was believed to increase the risk for fragility fracture due to a reduction in bone density while, conversely, an increase in body weight would maintain bone density and eventually prevent fragility fracture. However, in recent years, it has been considered important to not simply observe a change in weight but rather a change in muscle mass. Therefore, increase in body weight—not due to muscle mass, but to body fat—could increase the risk for osteoporosis.⁽⁷⁾ In fact, studies involving Korean women have demonstrated that high body fat mass can increase the risk for bone density reduction in the femoral neck.⁽⁸⁾ In another study involving postmenopausal women, the optimal body mass index (BMI) with minimal risk for osteoporosis was 23–24.9 kg/m².⁽⁹⁾ As such, weight gain is no longer believed to prevent osteoporosis.

Although several studies have investigated the relationship between obesity and osteoporosis in Koreans, only a few have examined the impact of obesity on fragility fractures. Accordingly, this study aimed to investigate the relationship between BMI—an index of obesity—and fragility fractures in postmenopausal Korean women.

Methods

Participants

A total of 11,604 women registered in the 4th National Health and Nutrition Examination Survey (2008–2009) were selected as primary participant group. Of these, 3023 were postmenopausal, ≥ 40 years of age, and had available bone density test data, and were selected as the secondary participant group. After exclusion of 909 women with uncertain examination records, 2114 were ultimately included as the final participant group (Fig. 1).

Definitions and measurements

BMI was determined by dividing body weight (kg) by height (m²). Based on WHO standards for the Western Pacific region and Korean Society for the Study of Obesity standards, BMI < 18.5 kg/m² was defined as underweight, $18.5 \leq$ to < 25 kg/m² as normal weight, and ≥ 25 kg/m² as obese.⁽¹⁰⁾ In the present study, those classified as overweight, with BMI $23 \leq$ to < 25 kg/m², were allocated to the normal weight group according to the National Health and Nutrition Examination Survey questionnaire.

For fragility fractures, responses to the question “Have you experienced fragility fractures?”, were divided into sites such as the “spine,” “hip,” and “wrist,” with responses “Yes,” “No,” “Not Applicable,” and “I don't know.” Those who responded “I don't know” were already excluded during the selection process, and those who responded with “No” and “Not Applicable” were allocated to a group with no fragility fractures

because the reasoning for responding with “Not Applicable” would have to be that “they haven't experienced it yet.” Participants who responded with “Yes” to any of the three sites were classified into a group with fragility fractures, and those that responded with “No” to all three sites were placed in the group without fragility fractures.

Bone density in the participants was measured using dual energy X-ray absorptiometry and a fan-beam densitometer (Discovery, Hologic Inc., Bedford, MA, USA), and the lumbar spine and left femur were measured. The units of bone density were area density, g/cm². In addition, according to the osteoporosis diagnostic criteria set by the WHO, those with T-score > -1.0 were classified as normal, T-score > -2.5 and ≤ -1.0 as osteopenia, and T-score ≤ -2.5 as osteoporosis.⁽¹¹⁾

In the health behavior questionnaire, those who responded with “smoking” to the question on “Current smoking status” was classified as “current smoker” and those who responded with “smoked in the past but quit” and “Never smoked” as “none.” For alcohol status, considering the guidelines for moderate drinking of Koreans, the frequency of drinking from the question “Drinking frequency in a year” and the amount from the question “Amount you drink at a time” were both considered. Those who do not drink at all were classified as “non-drinkers,” those ≥ 65 years of age and who consumed < 2 glasses per week, or < 65 years of age and consumed < 4 glasses per week as “moderate drinkers,” and the remainder as “heavy drinkers.”⁽¹²⁾ The moderate exercise was classified based on the questionnaire about whether one exercises moderately for ≥ 30 min at least five times per week.

Statistical analysis

During analysis of data from the National Health and Nutrition Examination Survey, the following errors were corrected through the complex sample design: inclusion errors due to differences in the number of households and populations between the sample design period and the survey period; unequal selection probabilities; and nonresponse error of those who did not participate in the survey. For this, the primary sampling unit, k-strata, and weight were specified.⁽¹³⁾

Participants were divided into three groups according to BMI: underweight, normal weight, and obese. The complex samples general linear model was used for continuous variables such as age, height, waist circumference, age at menopause, and bone density (BMC, T-score) for mean comparison. For categorical variables, such as fragility fracture rate, treatment history and family history of osteoporosis, history of rheumatoid arthritis, smoking status, drinking status, and moderate exercise, Rao-Scott chi-square test was used.

Complex samples logistic regression was used to analyze the relationship between BMI and fragility fracture rate. During analysis, variables that could affect fragility fractures such as age, treatment history and family history of osteoporosis, history of rheumatoid arthritis, smoking status, drinking (i.e., alcohol) status, and moderate exercise, were corrected.

All statistical analyses in this study were performed using SPSS version 22 (IBM Corporation, Armonk, NY, USA).

Results

General characteristics of the participants

The mean (\pm SD) age of the normal weight group was 59.01 ± 0.42 years, which was not statistically different from the mean age of the underweight group (61.43 ± 3.00 years) but was significantly different from that of the obese group (60.98 ± 0.44 years) ($p = 0.001$). Among body composition items, mean height was not different among the three groups; however, weight, BMI, and waist circumference were different from the normal weight group. The mean weight of the normal, underweight, and obese groups was 53.62 ± 0.21 kg, 41.43 ± 1.05 kg, and 64.65 ± 0.28 kg, respectively; the differences were statistically significant (underweight, $p < 0.001$; obese, $p < 0.001$). The mean BMI of the normal, underweight, and obese groups was 22.49 ± 0.06 kg/m², 17.55 ± 0.20 kg/m², and 27.31 ± 0.09 kg/m², respectively (underweight group, $p < 0.001$; obese group, $p < 0.001$). The mean waist circumferences of the normal, underweight, and obese groups were 76.96 ± 0.29 cm, 65.30 ± 0.86 cm, and 89.47 ± 0.37 cm, respectively, which was significantly different from the normal weight group (underweight group, $p < 0.001$; obese, $p < 0.001$). The average age at menopause was not different among the groups (normal weight, 48.59 ± 0.22 years; underweight, 45.61 ± 1.66 years; obese, 48.48 ± 0.26 years). The average weight-corrected appendicular skeletal muscle mass was 34.29 ± 0.37 for normal weight group, 49.43 ± 3.35 for underweight group, and 28.52 ± 0.33 for the obese group, with the underweight group and the obese group showing statistically significant difference compared to the normal weight group (each $p < 0.001$). In case of bone density (g/cm²), the average bone density of the femoral neck (0.79 ± 0.03) and the entire femur (0.94 ± 0.03) in the underweight group was significantly higher than that of the normal weight group (femoral neck average, 0.73 ± 0.01 ; femur average 0.88 ± 0.01) (each $p = 0.035$, $p = 0.029$). In the case of T-score, only the average T-score of the femoral neck in the underweight group (-0.35 ± 0.24) was significantly different from that of the normal weight group (-0.87 ± 0.06) ($p = 0.032$). Regarding fragility fracture rate, there were differences among the three groups: underweight, $5.9\% \pm 2.9$; normal, $1.1 \pm 0.3\%$; and obese, $3.0 \pm 0.7\%$ ($p = 0.001$). There were no statistical differences in treatment history and family history of osteoporosis, history of rheumatoid arthritis, smoking status, drinking status, and moderate exercise among the three groups (Table 1).

Table 1
Characteristics for postmenopausal women according to BMI

	Underweight	Normal	Obesity	p-value
	(BMI < 18.5) N = 45	(BMI ≥ 18.5 and < 25) N = 1234	(BMI ≥ 25) N = 835	(χ^2)
Est. number (n) (%)	105855 (2.1%)	3030556 (60.6%)	1867253 (37.3%)	
Age (years)	61.43 ± 3.00	59.01 ± 0.42	60.98 ± 0.44 ^b	
Height (cm)	153.36 ± 1.61	154.28 ± 0.22	153.77 ± 0.28	
Weight (kg)	41.43 ± 1.05 ^c	53.62 ± 0.21	64.65 ± 0.28 ^c	
BMI (kg/m ²)	17.55 ± 0.20 ^c	22.49 ± 0.06	27.31 ± 0.09 ^c	
Waist circumference (cm)	65.30 ± 0.86 ^c	76.96 ± 0.29	89.47 ± 0.37 ^c	
Menopausal age (years)	45.61 ± 1.66	48.59 ± 0.22	48.48 ± 0.26	
Weight-adjusted ASM	49.43 ± 3.35 ^c	34.29 ± 0.37	28.52 ± 0.33 ^c	
BMD (g/cm ²)				
Lumbar spine total	0.92 ± 0.03	0.90 ± 0.01	0.91 ± 0.01	
Femur neck	0.79 ± 0.03 ^a	0.73 ± 0.01	0.72 ± 0.01	
Femur total	0.94 ± 0.03 ^a	0.88 ± 0.01	0.88 ± 0.01	
BMD (T-score)				
Lumbar spine total	-0.80 ± 0.22	-0.91 ± 0.06	-0.88 ± 0.06	
Femur neck	-0.35 ± 0.24 ^a	-0.87 ± 0.06	-0.89 ± 0.06	
Femur total	0.31 ± 0.18	-0.03 ± 0.05	-0.07 ± 0.06	
Fragility fracture (%)	5.9(± 2.9)	1.1(± 0.3)	3.0(± 0.7)	0.001 (11.186)

All values are weighted value and presented mean(± standard deviation) or percent(± standard deviation).

a, b and c are presented p-value < 0.05, < 0.01 and < 0.001, respectively.

BMI, body mass index;ASM, appendicular skeletal muscle mass;BMD, bone mineral density;OP, osteoporosis;FHx, familial history.

	Underweight	Normal	Obesity	p-value
Treatment of OP (%)				0.369
None	91.8(± 3.6)	91.4(± 1.0)	93.2(± 1.1)	(1.938)
Current treatment	8.2(± 3.6)	8.6(± 1.0)	6.8(± 1.1)	
FHx of osteoporosis (%)				0.540
No	78.3(± 8.0)	85.1(± 1.3)	86.0(± 1.6)	(1.859)
Yes	21.7(± 8.0)	14.9(± 1.3)	14.0(± 1.6)	
Rheumatoid arthritis (%)				0.156
No	94.0(± 3.7)	96.3(± 0.6)	94.3(± 0.9)	(3.835)
Yes	6.0(± 3.7)	3.7(± 0.6)	5.7(± 0.9)	
Smoking status (%)				0.056
None	86.3(± 6.6)	95.6(± 0.7)	95.6(± 0.9)	(7.671)
Current smoker	13.7(± 6.6)	4.4(± 0.7)	4.4(± 0.9)	
Alcohol consumption (%)				0.242
Non-drinker	65.4(± 9.3)	52.4(± 1.6)	49.1(± 2.2)	(8.583)
Moderate drinker	23.9(± 7.5)	40.4(± 1.6)	44.6(± 2.3)	
Heavy drinker	10.8(± 7.6)	7.2(± 0.9)	6.3(± 1.1)	
Moderate exercise (%)				0.264
Yes	6.9(± 4.1)	12.8(± 1.3)	15.4(± 1.9)	(3.855)
No	93.1(± 4.1)	87.2(± 1.3)	84.6(± 1.9)	
All values are weighted value and presented mean(± standard deviation) or percent(± standard deviation).				
a, b and c are presented p-value < 0.05, < 0.01 and < 0.001, respectively.				
BMI, body mass index;ASM, appendicular skeletal muscle mass;BMD, bone mineral density;OP, osteoporosis;FHx, familial history.				

Difference between vertebral and non-vertebral fracture rate according to BMI via Rao-Scott chi-squared test

The overall fragility fracture rates for the underweight, normal weight, and obese groups were 5.9%, 1.1%, and 3.0%, respectively, and the difference was statistically significant ($p = 0.001$, $\chi^2 = 11.186$). When

fracture rates were compared between the vertebral and non-vertebral fracture rates, vertebral fracture rate for the underweight group ($4.5 \pm 2.6\%$) was significantly higher compared with the normal weight group ($0.6 \pm 0.2\%$) and obese group ($0.9 \pm 0.4\%$) ($p = 0.014$, $\chi^2 = 7.644$). In the case of non-vertebral fracture rate, that of the obese group ($2.3 \pm 0.6\%$) was relatively higher than that of the normal weight group ($0.7 \pm 0.3\%$) and underweight group ($1.4 \pm 1.4\%$), with a statistically significant difference among the three groups ($p = 0.011$, $\chi^2 = 8.040$) (Fig. 2).

Odds ratio for fragility fracture according to multiple logistic regression analysis

The odds ratio for fragility fracture in the underweight and obese groups was compared with the normal weight group via multiple logistic regression analysis. In model 1, which was not corrected, the odds ratio for fracture in the underweight group was 5.48 (95% CI 1.66–17.76) and 2.72 (95% CI 1.38–5.37) in the obese group. In model 2, which was corrected for age and family history and treatment history of osteoporosis, odds ratio for the underweight group was 5.14 (95% CI 1.77–14.93) and 3.12 (95% CI 1.50–6.48) in the obese group. In model 3, which was corrected for age, family history and treatment history of osteoporosis, history of rheumatoid arthritis, smoking status, drinking status, and moderate exercise, the odds ratio for the underweight group was 5.51 (95% CI 1.88–16.13) and 3.19 (95% CI 1.51–6.74) for the obese group (Table 2).

Table 2
Odds ratio(OR) of fragility fracture for postmenopausal women by multivariate logistic regression analysis.

	OR (95% CI)
Normal weight (BMI \geq 18.5 and $<$ 25)	1 (Reference)
Underweight (BMI $<$ 18.5)	
Model 1	5.48 (1.66–17.76)
Model 2	5.14 (1.77–14.93)
Model 3	5.51 (1.88–16.13)
Obesity (BMI \geq 25)	
Model 1	2.72 (1.38–5.37)
Model 2	3.12 (1.50–6.48)
Model 3	3.19 (1.51–6.74)
Model 1 : Crude	
Model 2 : Adjusted for age, family history of OP and treatment of OP.	
Model 3: Adjusted for age, family history of OP, treatment of OP, presence of rheumatoid arthritis, smoking status, alcohol consumption and moderate exercise.	
BMI, body mass index;OP, osteoporosis.	

Fragility fractures were classified as vertebral fractures and non-vertebral, and logistic regression analysis was performed after correcting for age, family history and treatment history of osteoporosis, history of rheumatoid arthritis, smoking status, drinking status, and moderate exercise. In the underweight group, the odds ratio for vertebral fracture was 6.05 (95% CI 1.61–22.68) times higher than the normal weight group. In the obese group, there was no statistically significant difference in the odds ratio for vertebral fracture, while the non-vertebral fracture odds ratio was observed to be 3.73 (95% CI 1.33–10.44) times higher. When non-vertebral fractures were compared after dividing them into hip and wrist, the obese group had an odds ratio for hip fracture 8.29 (95% CI 1.04–66.37) times higher and 3.73 (95% CI 1.21–11.43) times higher for wrist fracture (Table 3).

Table 3
Odds ratio(OR) of vertebral fracture(VF) and non-vertebral fracture(NVF) according to BMI.

	VF	NVF		
	OR (95% CI)	OR (95% CI)		
	Total	Total	Hip	Wrist
Underweight (BMI < 18.5)	6.05 (1.61–22.68)	1.78 (0.21–15.31)	6.84 (0.24–195.31)	1.95 (0.23–16.81)
Normal (BMI ≥ 18.5 and < 25)	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)
Obesity (BMI ≥ 25)	1.66 (0.49–5.56)	3.73 (1.33–10.44)	8.29 (1.04–66.37)	3.73 (1.21–11.43)
Adjusting for age, family history of osteoporosis, treatment of osteoporosis, presence of rheumatoid arthritis, smoking status, alcohol consumption and moderate exercise.				
BMI, body mass index				

Discussion

The purpose of this study was to investigate the relationship between BMI and fragility fracture(s) in postmenopausal Korean women. In both the underweight and obese groups, the fragility fracture rates were 5.51 times and 3.19 times higher, respectively, compared with the normal weight group. In particular, the underweight group exhibited an odds ratio for vertebral fracture that was 6.05 times higher, and the obese group exhibited an odds ratio for non-vertebral fracture that was 3.73 times higher. As such, the most significant finding of the present study was that postmenopausal women who were underweight or obese exhibited higher rates of fragility fracture(s).

The findings of high fragility fracture rate in the underweight group were consistent with previous studies; however, there were slight differences in fracture sites for each study. According to one study, underweight individuals with a BMI < 20 kg/m² demonstrated a hip fracture rate twice as high as those with a BMI of 25 kg/m².⁽¹⁴⁾ Another study found that for individuals with a BMI < 20 kg/m², the non-vertebral fracture rate was 2.45 times higher.⁽¹⁵⁾ The reason for this is that the risk for falls increases with lower BMI.⁽¹⁶⁾ However, previous studies have shown that lower weight increases lumbar spine fractures, similar to the results of the present investigation. One study found that the decrease in BMI increased the vertebral fracture rate.⁽¹⁷⁾ Other studies reported that lumbar spine fracture rate was 2.79 times higher for underweight individuals with BMI < 18.5 kg/m² compared to those with BMI > 24 kg/m².⁽¹⁸⁾ Studies have reported that the reason for high fragility fracture rate in underweight individuals is related to muscle loss.

According to one study, sarcopenia is associated with older age, low BMI, and low bone density.⁽¹⁹⁾ Although this explains the increase in fragility fracture rate,⁽²⁰⁾ items for diagnosing sarcopenia were omitted in this study; as such, an accurate comparison could not be made.

In this study, there was no statistical difference in the rate of lumbar spine fractures in the obese group, which was similar to other previous studies. One study that examined changes in lumbar spine bone density in individuals with weight changes showed that individuals with weight gain had increased lumbar spine bone density compared to those with weight loss.⁽²¹⁾ As a result, we can predict that as weight increases, spinal bone density increases, and the fracture rate decreases. Another study showed that high BMI and waist circumference in women were associated with a decrease in bone density due to increase in fat mass; however, whether these factors affect the lumbar spine fracture rate needs further study.⁽²²⁾

Recently, it was reported that obesity is related to the site of fragility fractures. One study found that obesity led to lower risk of lumbar and femur fractures⁽¹⁴⁾; however, another study showed that obesity increased the non-vertebral fracture rate. In particular, the proximal humerus fracture rate was 1.28 times higher, the femur fracture rate was 1.7 times higher, and the ankle fracture rate was 1.5 times higher.^(23, 24) Another study reported that high BMI led to a decrease in the relative risk for fragility fracture in the spine, hip, and wrist, but an increase in fragility fractures of the ankle.⁽²⁵⁾ In postmenopausal women, obesity led to an increase in humerus fracture rates.⁽²⁶⁾ As such, one reason why obesity is associated with fractures could be that high body fat levels can reduce bone density. One study reported that the bone loss effect in the entire hip and the femoral neck was more prominent in Korean middle-age women with normal weight and a body fat percentage $\geq 36\%$.⁽²⁷⁾

The non-vertebral fracture rate was higher in the obese group, unlike the underweight group, which could be explained by the fact that the obese group exhibited significantly lower weight-corrected appendicular skeletal muscle mass compared with the normal weight group. Appendicular skeletal muscle mass is used as one metric to define sarcopenia,⁽²⁸⁾ and it is common to use height-corrected appendicular skeletal muscle mass. However, the reason for comparing weight-corrected appendicular skeletal muscle mass in this study was based on a study in which Korean women with height-corrected appendicular skeletal muscle mass demonstrated a poor correlation with age-related muscle mass reduction; therefore, it was necessary to use weight-corrected appendicular skeletal muscle mass.⁽²⁹⁾ According to one study, sarcopenia with reduced appendicular skeletal muscle mass was associated with a decrease in bone density.⁽³⁰⁾ Although this decrease in bone density may be directly related to fractures, it is also possible that the risk for falls is increased due to a decrease in appendicular skeletal muscle mass.⁽³¹⁾

Generalizing the results of the present investigation would be difficult given that it was a cross-sectional study limited to postmenopausal women.

Conclusions

The most significant finding was that obesity did not reduce the rate of fractures in postmenopausal women. Further studies investigating the relationship between obesity and fragility fractures appear to be warranted; however, results of this study demonstrated that postmenopausal weight gain or loss could increase the risk for fragility fractures. As such, maintaining adequate bone health through weight control, exercise, and regular examination of bone density may be important in improving the quality of life in old age.

Abbreviations

BMI

Body mass index

WHO

World health organization

Declarations

Ethics approval and consent to participate

The National Health and Nutrition Examination Survey, conducted under Article 16 of the National Health Promotion Act, is a statutory survey addressing the health behavior, prevalence of chronic disease, and food and nutrition intake of Korean citizens, and is a government-designated statistic based on Article 17 of the Statistics Act (approval number 117002). The survey was conducted every three years from the first (1998) to the third (2005) period. After its reorganization into an annual survey system, it has been conducted annually from the fourth period (2007-2009). It corresponds to research conducted by the government for public welfare in accordance with the Bioethics Act, and provides raw data to all researchers through the website of the Korean Centers for Disease Control and Prevention (<https://knhanes.cdc.go.kr>). In addition, the National Health and Nutrition Examination Survey was conducted with the approval of the Institutional Review Board of Korea Centers for Disease Control and Prevention (Reference numbers 2008-04EXP-01-C and 2009-01CON-03-2C). The present study was approved for waiver of review by the Chungnam National University Hospital Institutional Review Board (Daejeon, South Korea; Institutional Review Board number: 2020-04-102).

Consent for publication

None

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

None

Funding

None

Authors' contributions

JK: acquiring, analyzing and interpreting data, drafting the manuscript; SL: conceiving and designing this study, revising the manuscript; SSK, JPL, JSK, JGJ, SJY, KPK, CKP, YHK: acquiring the data. All authors have read and approved the submitted version. All authors have agreed to take personal responsibility for their contributions.

Corresponding author

Correspondence to Sami Lee.

Acknowledgements

None

References

1. Kim J, Kim B, Lee H, Choi H, Won C. The relationship between prevalence of osteoporosis and proportion of daily protein intake. *Korean J Fam Med*. 2013;34(1):43–8.
2. Moon JH, Kim LO, Kim HJ, Kong MH. Evaluation of the predictive index for osteoporosis as a clinical tool to identify the risk of osteoporosis in Korean men by using the Korea National Health and Nutrition Examination Survey data. *Korean J Fam Med*. 2016;37(6):346–50.
3. World Health Organization. Guidelines for preclinical evaluation and clinical trials in osteoporosis. Geneva: World Health Organization; 1998.
4. Park C, Ha YC, Jang S, Jang S, Yoon HK, Lee YK. The incidence and residual lifetime risk of osteoporosis-related fractures in Korea. *J Bone Miner Metab*. 2011;29(6):744–51.
5. Ley CJ, Lees B, Stevenson JC. Sex- and menopause-associated changes in body-fat distribution. *Am J Clin Nutr*. 1992;55(5):950–4.
6. Park HA, Kim HJ, Kim TJ, Park JJ, Park JK. Weight and bone mineral density – The summary of epidemiological evidence. *Korean J Fam Med*. 2009;30:167–74.
7. Tomlinson DJ, Erskine RM, Morse CI, Onambélé GL. Body fat percentage, body mass index, fat mass index and the ageing bone: their singular and combined roles linked to physical activity and diet. *Nutrients*. 2019;11(1):pii: E195.
8. Kim J, Kwon H, Heo BK, et al. The Association between fat mass, lean mass and bone mineral density in premenopausal women in Korea: A cross-sectional study. *Korean J Fam Med*. 2018;39(2):74–84.

9. Lee JH, Kim JH, Hong AR, Kim SW, Shin CS. Optimal body mass index for minimizing the risk for osteoporosis and type 2 diabetes. *Korean J Intern Med.* 2019;30.
10. Na YM, Park HA, Kang JH, et al. Obesity, obesity related disease, and disability. *Korean J Fam Med.* 2011;32(7):412–22.
11. Kanis JA, Melton LJ 3rd, Christiansen C, Johnston CC, Khaltsev N. The diagnosis of osteoporosis. *J Bone Miner Res.* 1994;9:1137–41.
12. Lee S, Kim JS, Jung JG, Oh MK, Chung TH, Kim J. Korean alcohol guidelines for moderate drinking based on facial flushing. *Korean J Fam Med.* 2019;40(4):204–11.
13. Kim Y. The Korea National Health and Nutrition Examination Survey (KNHANES): Current status and challenges. *Epidemiol Health.* 2014;36:e2014002.
14. De Laet C, Kanis JA, Odén A, et al. Body mass index as a predictor of fracture risk: a meta-analysis. *Osteoporos Int.* 2005;16(11):1330–8.
15. Deloumeau A, Moltó A, Roux C, Briot K. Determinants of short term fracture risk in patients with a recent history of low-trauma non-vertebral fracture. *Bone.* 2017;105:287–91.
16. Szewieczek J, Mazur K, Wilczyński K. Geriatric falls in the context of a hospital fall prevention program: Delirium, low body mass index, and other risk factors. *Clin Interv Aging.* 2016;11:1253–61.
17. Zvekic-Svorcan J, Aleksic J, Jankovic T, et al. Capture the vertebral fracture: Risk factors as a prediction. *J Back Musculoskelet Rehabil.* 2019;32(2):269–76.
18. Chen YL, Liu YC, Wu CH, et al. Role of BMI and age in predicting pathologic vertebral fractures in newly diagnosed multiple myeloma patients: A retrospective cohort study. *Hematol Oncol.* 2018;36(2):407–15.
19. Wang WF, Lin CW, Xie CN, et al. The association between sarcopenia and osteoporotic vertebral compression refractures. *Osteoporos Int.* 2019;30(12):2459–67.
20. Woo J. Sarcopenia. *Clin Geriatr Med.* 2017;33(3):305–14.
21. Lee HR, Hong SS, Lee SY, et al. The impact of body weight change on bone mineral density of the lumbar spine in perimenopausal women: A retrospective, one-year follow-up study. *Korean J Fam Med.* 2011;32(4):219–25.
22. Luo J, Lee RY. How does obesity influence the risk of vertebral fracture? Findings from the UK Biobank participants. *JBMR Plus.* 2020;4(5):e10358.
23. Compston JE, Watts NB, Chapurlat R, et al. Obesity is not protective against fracture in postmenopausal women: GLOW. *Am J Med.* 2011;124(11):1043–50.
24. Prieto-Alhambra D, Premaor MO, Fina Aviles F, et al. The association between fracture and obesity is site-dependent: a population-based study in postmenopausal women. *J Bone Miner Res.* 2012;27(2):294–300.
25. Compston JE, Flahive J, Hosmer DW, et al. GLOW Investigators. Relationship of weight, height, and body mass index with fracture risk at different sites in postmenopausal women: the Global Longitudinal study of Osteoporosis in Women (GLOW). *J Bone Miner Res.* 2014;29(2):487–93.

26. Mpalaris V, Anagnostis P, Goulis DG, Iakovou I. Complex association between body weight and fracture risk in postmenopausal women. *Obes Rev.* 2015;16(3):225–33.
27. Kim DH, Lim H, Chang S, Kim JN, Roh YK, Choi MK. Association between body fat and bone mineral density in normal-weight middle-aged Koreans. *Korean J Fam Med.* 2019;40(2):100–5.
28. Chen LK, Woo J, Assantachai P, et al. Asian Working Group for Sarcopenia: 2019 Consensus Update on Sarcopenia Diagnosis and Treatment. *J Am Med Dir Assoc.* 2020;21(3):300–7.e2.
29. Kim YS, Lee Y, Chung YS, et al. Prevalence of sarcopenia and sarcopenic obesity in the Korean population based on the Fourth Korean National Health and Nutritional Examination Surveys. *J Gerontol A Biol Sci Med Sci.* 2012;67(10):1107–13.
30. Go SW, Cha YH, Lee JA, Park HS. Association between sarcopenia, bone density, and health-related quality of life in Korean men. *Korean J Fam Med.* 2013;34(4):281–8.
31. National Institute for Health and Care Excellence (UK). Osteoporosis: assessing the risk of fragility fracture. In: National Institute for Health and Care Excellence: Clinical Guidelines. 2017. Available from: <https://www.nice.org.uk/guidance/cg146>.

Figures



Figure 1

Study population. KNHANES, Korean National Health and Nutrition Examination Survey; DXA, Dual-energy X-ray absorptiometry.

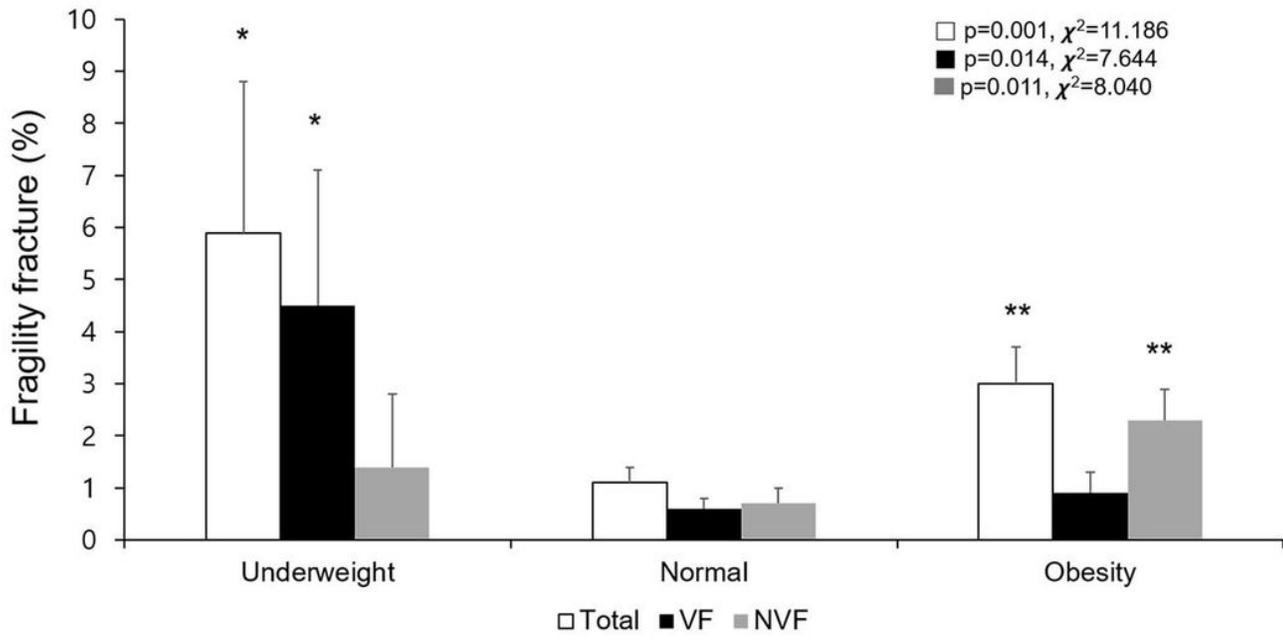


Figure 2

Prevalence of fragility fracture according to body mass index. * and ** means $p < 0.05$ and $p < 0.01$ compared to normal BMI by Rao-scott chi-square test. VF, vertebral fracture; NVF, non-vertebral fracture; BMI, body mass index.