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Association between Body Mass Index and Prevalence of Asthma in Korean Adults

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We evaluated the association between body mass index (BMI) and the prevalence of asthma. Using data from the 2015 Korean Community Health Survey, 214,971 participants aged between 19 and 106 years were included in this study. Asthma was defined based on the self-report of physician diagnosis. BMI was classified as underweight (<18.5 kg/m^2), normal weight (18.5 kg/m^2 ≤ BMI<23.0 kg/m^2), overweight (23.0 kg/m^2 ≤ BMI<27.4 kg/m^2), and obese (≥27.5 kg/m^2) based on the BMI categories for Asians by the World Health Organization. Multiple logistic regression analysis was performed with sampling weights to evaluate the association between BMI and asthma after adjusting for age, educational level, income, type of residential area, smoking status, alcohol consumption, physical activity, hypertension, and diabetes. In men, BMI had an inverted J-shaped association with the prevalence of asthma, with an odds ratio of 1.88 (95% confidence interval [CI]: 1.89-2.24) for underweight and 1.12 (95% CIs: 0.97-1.29) for obesity. In women, BMI had a J-shaped association with the prevalence of asthma, with an odds ratio of 1.05 (95% CIs: 0.91-1.22) for underweight and 2.29 (95% CIs: 2.06-2.56) for obesity. In conclusion, in a nationally representative sample of Korean adults, the association between BMI and the prevalence of asthma varied between the sexes. This suggests that malnutrition and obesity are involved in the pathophysiology of asthma.

Key Words: *Body Mass Index; Asthma; Obesity; Thinness*

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INTRODUCTION

Asthma is a lung disease characterized by reversible or treatable airway obstruction, increased bronchial responsiveness, and chronic respiratory tract inflammation.[1] The prevalence of asthma is increasing worldwide.[2] Asthma affects 358 million people and has the highest prevalence of any chronic respiratory disease.[3] The prevalence of asthma has also increased in Korea, imposing a considerable economic burden on the individuals and society.[4] However, the reason for the recent increase in the prevalence of asthma is unclear.[5]

The prevalence and economic burden of obesity are increasing.[6,7] Based on the Korea National Health and Nutrition Examination Survey (KNHANES), the prevalence of obesity increased from 25.1% for men and 26.2% for women in 1998 to 41.6% for men and 25.6% for women in 2017.[8] Kang et al.[9] estimated that the socioeconomic burden of obesity in Korea increased from approximately 350 million United States dollars (USD) in 1998 to approximately 1.8 billion USD in 2005.

Previous studies have found an association between body mass index (BMI) and asthma, but this association remains controversial.[10-25] Many studies have reported a linear relationship between BMI and the prevalence of asthma,[10-18] while others have identified a J-or U-shaped relationship.[5,19-22] However, some studies found no association between BMI and asthma[23,24] or found an association only in women[10,13,15,19,25] or men.[16] Previous studies focused on specific age groups[10,16] or a single sex.[13,20] In Korea, the studies conducted using KNHANES data had an insufficient statistical power because of the low prevalence of

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asthma. Therefore, the aim of this study was to evaluate the association between BMI and the prevalence of asthma in a large nationally representative sample of Korean adults and assess whether the association was nonlinear or linear.

MATERIALS AND METHODS

1. Study population

Data was obtained from the 2015 Korean Community Health Survey (KCHS),[26] which was based on data from 254 communities and was conducted by the Korea Center for Disease Control in 17 major cities, 254 community health centers, and 35 community universities. Well-trained interviewers visited selected households, and members of the households older than 19 years were surveyed using computer-assisted personal interviews. The survey was conducted from August 31, 2015 to November 8, 2015. Initially, 228,558 participants aged 19 years or above were recruited from the 2015 KCHS. Among them, 13,587 participants were excluded because of a lack of knowledge regarding BMI, asthma, or the covariates including socioeconomic, demographic, health, and behavioral factors. Finally, a total of 214,971 participants were analyzed.

This study was a secondary analysis of a dataset publicly available on the KCHS website (https://chs.cdc.go.kr). Therefore, institutional review board approval was not required for this study.

2. Prevalence of asthma

Participants were considered to have asthma if they answered the following question affirmatively. "Have you ever been diagnosed with asthma by a doctor?"

3. BMI

BMI was calculated using self-reported weight and height. According to the World Health Organization, BMI for Asians is classified as follows[27]: underweight, <18.5 kg/m^2; normal weight, 18.5 kg/m^2 ≤ BMI<23.0 kg/m^2; overweight; 23.0 kg/m^2 ≤ BMI<27.5 kg/m^2; and obese, ≥27.5 kg/m^2.

4. Covariates

Data on demographic factors, smoking status, alcohol consumption, physical activity and comorbidities were collected using interviews. The demographic factors included age, residential area (urban or rural), marital status (single, married, or divorced/widowed/separated), household income (low, ≤1.00 million Korean Won (KRW); medium-low, 1.01-3.00 million KRW; medium-high, 3.01-5.00 million KRW; or high, ≥5.01 KRW), and educational level (low, elementary school or below; medium, middle or high school; or high, college or above). Based on the smoking status, participants were characterized as former smokers, current smokers or never smokers. Alcohol consumption was defined as drinking alcohol once or more in a month in the past year. Physical activity was categorized into moderate-intensity (≥30 min a day, 5 days a week) and vigorous-intensity (≥20 min a day, 3 days a week) physical activities. Hypertension and diabetes were defined by the self-report of physician diagnosis.

5. Statistical analysis

Data were analyzed separately for both sexes. Table 1 shows the general characteristics of the participants based on the BMI category. Categorical variables are expressed as the observed number and percentage and were compared using the Pearson's chi-square test. Continuous variables are expressed as mean and standard deviation, and were compared using the analysis of variance.

The lowest risk category of BMI, i.e., overweight in men and normal weight in women, was used as the reference category. A multiple logistic regression analysis was performed with sampling weights to evaluate the association between BMI and the prevalence of asthma after adjusting for age, educational level, income, residence, smoking status, alcohol consumption, physical activity, hypertension, and diabetes. The odd ratios (OR) and corresponding 95% confidence intervals (CIs) are presented. Statistical significance was set at p-value <0.05. Statistical analyses were performed with Stata version 15.0 (Stata Corp., College Station, TX).

RESULTS

Table 1 and 2 show the general characteristics of the participants based on the BMI category and sex. The prevalence of being underweight was 2.8% in men and 7.1% in women and the prevalence of obesity was 10.7% in men and 7.2% in women. In both sexes, participants with higher BMI tended to be married, engage in more physical activity, and have higher rates of hypertension and diabetes. Men with high BMI tended to be younger; have higher educational levels, monthly income, and alcohol consumption levels; and live in urban areas. In contrast, women with high BMI tended to be older; have lower educational levels, monthly income, and alcohol consumption levels; and live in rural areas.

Table 3 shows the OR for the prevalence of asthma based on the BMI category. In men, the relationship between asthma and BMI exhibited an inverted J-shape curve. When overweight was used as the reference, the OR for asthma was 3.01 (95% CI, 2.57-3.54) for underweight, 1.18 (95% CI, 1.09-1.29) for normal-weight, and 1.02 (95% CI, 0.89-1.17) for obesity. After adjustment for the potential confounders, this inverted J-shaped association was substantially attenuated but still significant for individuals with underweight (OR; 1.88, 95% CIs; 1.59-2.22). In contrast, in women, the relationship between asthma and BMI showed a J-shaped curve. When normal weight was used as the reference, the OR for asthma was 1.14 (95% CIs, 0.98-1.32) for underweight, 1.47 (95% CIs, 1.37-1.59) for overweight, and 2.78 (95% CIs, 2.51-3.09) for obesity. After adjustment for the potential confounders, this J-shaped association was slightly attenuated but was still significant

TABLE 1. Characteristics of 100,040 male participants based on the body mass index category

Characteristics	Underweight (<18.5 kg/m^2)	Normal weight (18.5-22.9 kg/m^2)	Overweight (23.0-27.4 kg/m^2)	Obese (≥27 kg/m^2)	Total (11.5-50.0 kg/m^2)	p-value
N (%)	2,776 (2.8)	37,514 (37.5)	49,064 (49.0)	10,686 (10.7)	100,040 (100.0)	
Age, mean (standard deviation)	58.3 (21.9)	52.2 (17.9)	51.5 (15.3)	46.2 (14.8)	51.4 (16.6)	<0.001
Educational level, n (%)						<0.001
Low, n (%)	981 (35.3)	6,594 (17.6)	6,207 (12.7)	988 (9.2)	14,770 (14.8)	
Medium, n (%)	1,119 (40.3)	16,282 (43.4)	21,634 (44.1)	4,448 (41.6)	43,483 (43.5)	
High, n (%)	676 (24.4)	14,638 (39.0)	21,223 (43.3)	5,250 (49.1)	41,787 (41.8)	
Marital status, n (%)						<0.001
Married, n (%)	1,729 (62.3)	26,158 (69.7)	38,049 (77.5)	7,612 (71.2)	73,548 (73.5)	
Never married, n (%)	697 (25.1)	8,191 (21.8)	7,458 (15.2)	2,400 (22.5)	18,746 (18.7)	
Divorced/widowed/separated, n (%)	350 (12.6)	3,165 (8.4)	3,557 (7.2)	674 (6.3)	7,746 (7.7)	
Household income, n (%)						<0.001
Low, n (%)	1,198 (43.2)	7,836 (20.9)	7,053 (14.4)	1,225 (11.5)	17,312 (17.3)	
Medium–low, n (%)	950 (34.2)	14,097 (37.6)	18,046 (36.8)	4,093 (38.3)	37,186 (37.2)	
Medium high, n (%)	413 (14.9)	10,147 (27.0)	15,090 (30.8)	3,455 (32.3)	29,105 (29.1)	
High, n (%)	215 (7.7)	5,434 (14.5)	8,875 (18.1)	1,913 (17.9)	16,437 (16.4)	
Living residence, n (%)	1,245 (44.8)	20,983 (55.9)	28,613 (58.3)	6,325 (59.2)	57,166 (57.1)	<0.001
Smoking status						<0.001
Non-smokers, n (%)	676 (24.4)	9,948 (26.5)	12,268 (25.0)	2,685 (25.1)	25,577 (25.6)	
Former-smokers, n (%)	1,015 (36.6)	12,949 (34.5)	19,649 (40.0)	3,859 (36.1)	37,472 (37.5)	
Current-smokers, n (%)	1,085 (39.1)	14,617 (39.0)	17,147 (34.9)	4,142 (38.8)	36,991 (37.0)	
Alcohol consumption, n (%)	1,420 (51.2)	25,768 (68.7)	35,930 (73.2)	7,845 (73.4)	70,963 (70.9)	<0.001
Physical activity, n (%)	491 (17.7)	9,888 (26.4)	13,896 (28.3)	3,024 (28.3)	27,299 (27.3)	<0.001
Prevalence of hypertension, n (%)	501 (18.0)	7,097 (18.9)	13,599 (27.7)	3,674 (34.4)	24,871 (24.9)	<0.001
Prevalence of diabetes, n (%)	235 (8.5)	3,453 (9.2)	5,659 (11.5)	1,444 (13.5)	10,791 (10.8)	<0.001
Prevalence of asthma, n (%)	183 (6.6)	1,020 (2.7)	1,129 (2.3)	250 (2.3)	2,582 (2.6)	<0.001

Values are expressed as mean ± standard deviation or number (%).
p-values were calculated from the analysis of variance for continuous variables and the Pearson's chi-square test for categorical variables.

for individuals who were overweight (OR, 1.31; 95%CIs, 1.21-1.42) and obesity (OR, 2.29; 95%CIs, 2.06-2.56).

DISCUSSION

In this cross-sectional study, we investigated the association between BMI and the prevalence of asthma in a nationally representative sample of Korean adults. Men showed an inverted J-shaped association between asthma and BMI, with the lowest risk for asthma found among those with a BMI of 24.0-24.5 kg/m^2. In contrast, women showed a J-shaped association between asthma and BMI, with the lowest risk of asthma found among those with a BMI of 21.5-22.0kg/m^2.

The association between BMI and asthma exhibited an inverted J-shaped curve in men and a J-shaped curve in women. The results of previous studies on the association between BMI and asthma are inconsistent. In three cross-sectional studies, a linear relationship between BMI and asthma was detected in both sexes.[11,14,17] In a longitudinal study of subjects aged 7-18 years, Gilliland et al.[16] found a linear relationship between BMI and asthma only in boys. In contrast, longitudinal studies by Chen et al.[28] in Canada and Shaheen et al.[10] in the United Kingdom revealed a linear relationship between BMI and asthma only in women. However, consistent with our findings, some studies have shown a nonlinear relationship between BMI and asthma. In a Chinese cross sectional study, Celedón et al.[21] found an inverted J-shaped association in men and a U-shaped association in women. In cross-sectional studies conducted in Italy by Negri et al.[22] and in the United States by Luder et al.,[5] the relationship between BMI and asthma was U-shaped in men and linear in women. Two studies evaluated the association between BMI and the prevalence of asthma in Korea using KNHANES data. Park et al.[23] found no relationship between BMI and asthma based on the fifth KNHANES data set of 17,000 participants. Similarly Lee et al.[24] found no association between BMI and asthma based on the sixth KNHANES data set. However, these studies had low statistical power because of low prevalence of asthma.

The pathophysiological explanation for the association between underweight and asthma risk in men is unclear. Also, due to the nature of cross-sectional studies, it is not possible to determine whether weight loss in childhood lead to asthma development or whether childhood asthma lead to growth disorders and malnutrition and continued until adulthood. Several animal studies have shown that

Table 2. Characteristics of 114,931 female participants based on the body mass index category

Characteristics	Underweight (<18.5 kg/m^2)	Normal weight (18.5-22.9 kg/m^2)	Overweight (23.0-27.4 kg/m^2)	Obese (≥27 kg/m^2)	Total (11.5-50.0 kg/m^2)	p-value
N (%)	8,189 (7.1)	57,540 (50.1)	40,960 (35.6)	8,242 (7.2)	114,931 (100.0)	
Age, mean (standard deviation)	46.7 (21.4)	49.9 (17.5)	55.5 (14.7)	55.0 (15.3)	52.1 (17.0)	<0.001
Educational level, n (%)						<0.001
Low, n (%)	2,179 (26.6)	13,734 (23.9)	13,658 (33.3)	3,058 (37.1)	32,629 (28.4)	
Medium, n (%)	1,918 (23.4)	21,275 (37.0)	18,449 (45.0)	3,638 (44.1)	45,280 (39.4)	
High, n (%)	4,092 (50.0)	22,531 (39.2)	8,853 (21.6)	1,546 (18.8)	37,022 (32.2)	
Marital status, n (%)						<0.001
Married, n (%)	3,973 (48.5)	37,355 (64.9)	28,975 (70.7)	5,562 (67.5)	75,865 (66.0)	
Never married, n (%)	2,472 (30.2)	8,977 (15.6)	2,501 (6.1)	634 (7.7)	14,584 (12.7)	
Divorced/widowed/separated, n (%)	1,744 (21.3)	11,208 (19.5)	9,484 (23.2)	2,046 (24.8)	24,482 (21.3)	
Household income, n (%)						<0.001
Low, n (%)	1,904 (23.3)	11,189 (19.4)	9,641 (23.5)	2,234 (27.1)	24,968 (21.7)	
Medium–low, n (%)	2,407 (29.4)	19,045 (33.1)	15,651 (38.2)	3,265 (39.6)	40,368 (35.1)	
Medium high, n (%)	2,302 (28.1)	16,718 (29.1)	10,256 (25.0)	1,882 (22.8)	31,158 (27.1)	
High, n (%)	1,576 (19.2)	10,588 (18.4)	5,412 (13.2)	861 (10.4)	18,437 (16.0)	
Living residence, n (%)	5,050 (61.7)	35,183 (61.1)	22,509 (55.0)	4,407 (53.5)	67,149 (58.4)	<0.001
Smoking status						<0.001
Non-smokers, n (%)	7,544 (92.1)	54,532 (94.8)	39,036 (95.3)	7,605 (92.3)	108,717 (94.6)	
Former-smokers, n (%)	241 (2.9)	1,302 (2.3)	925 (2.3)	294 (3.6)	2,762 (2.4)	
Current-smokers, n (%)	404 (4.9)	1,706 (3.0)	999 (2.4)	343 (4.2)	3,452 (3.0)	
Alcohol consumption, n (%)	3,400 (41.5)	24,425 (42.4)	14,957 (36.5)	2,700 (32.8)	45,482 (39.6)	<0.001
Physical activity, n (%)	1,237 (15.1)	11,320 (19.7)	8,327 (20.3)	1,595 (19.4)	22,479 (19.6)	<0.001
Prevalence of hypertension, n (%)	1,077 (13.2)	9,969 (17.3)	13,064 (31.9)	3,722 (45.2)	27,832 (24.2)	<0.001
Prevalence of diabetes, n (%)	387 (4.7)	3,614 (6.3)	4,665 (11.4)	1,493 (18.1)	10,159 (8.8)	<0.001
Prevalence of asthma, n (%)	215 (2.6)	1,325 (2.3)	1,372 (3.3)	509 (6.2)	3,421 (3.0)	<0.001

Values are expressed as mean ± standard deviation or number (%).
p-values were calculated from the analysis of variance for continuous variables and the Pearson's chi-square test for categorical variables.

Table 3. Odds ratio (95% confidence interval) for the prevalence of asthma based on the body mass index category

BMI category	Unadjusted		Adjusted	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Men				
Underweight (<18.5 kg/m^2)	3.01 (2.57-3.54)	<0.001	1.88 (1.59-2.22)	<0.001
Normal weight (18.5-22.9 kg/m^2)	1.18 (1.09-1.29)	<0.001	1.06 (0.97-1.16)	0.188
Overweight (23.0-27.4 kg/m^2)	1 (reference)	-	1 (reference)	-
Obese (≥27 kg/m^2)	1.02 (0.89-1.17)	0.758	1.12 (0.97-1.29)	0.121
Women				
Underweight (<18.5 kg/m^2)	1.14 (0.98-1.32)	0.079	1.05 (0.91-1.22)	0.485
Normal weight (18.5-22.9 kg/m^2)	1 (reference)	-	1 (reference)	-
Overweight (23.0-27.4 kg/m^2)	1.47 (1.37-1.59)	<0.001	1.31 (1.21-1.42)	<0.001
Obese (≥27 kg/m^2)	2.78 (2.51-3.09)	<0.001	2.29 (2.06-2.56)	<0.001

BMI: body mass index, OR: odds ratio, CI: confidence interval.
Adjusted for age, educational level, marital status, household income, living residence, smoking status, alcohol consumption, physical activity, and comorbidities (hypertension, diabetes).

prenatal and postnatal protein and calorie restrictions can cause permanent abnormalities in lung function and structure,[29,30] and in humans, factors that reduce fetal weight gain also inhibit lung growth.[31] In older children, an association between malnutrition and a significant decrease in lung function has been reported.[32] In addition, an association of fetal growth disorders with asthma has been identified in children,[33-35] adolescents,[36] and young adults.[10] Boys are particularly vulnerable to the effects of malnutrition because they have smaller airways size for lung size than girls.[37,38] Therefore, it is plausible that prenatal and postnatal malnutrition promoted abnormal lung growth or

asthma in some male participants in this study.

The relationship between obesity and asthma in women can be explained as follows: Several studies have suggested that the levels of female sex hormones such as estrogen and progesterone, which are affected by obesity, play an important role in the pathogenesis of asthma.[10,13,28] Obesity affects progesterone levels,[39-41] and progesterone levels increase the expression of β_2-adrenergic receptor,[42] which can affect asthma. Wahrenberg et al.[43] found that in 20 obese hyperandrogenic women, a mean weight loss of 8 kg was associated with a 2-fold increase in β_2-adrenergic receptor density, with a 5 to 7-fold increase in terbutaline sensitivity. Estrogens may affect asthma in different ways. Troisi et al.[44] showed that postmenopausal estrogen usage was associated with an increased risk of asthma. Hankinson et al.[45] reported that BMI positively associated with the plasma estrogen and estrone sulfate levels in postmenopausal women. Furthermore, according to Leenen et al.,[46] an abundance of visceral fat was significantly associated with elevated levels of sex hormones in women but not in men.

This study involved nationally representative data and a large sample with a high participation rate (93.8%). However, this study also had several limitations. First, because BMI was a self-reported, there is possibility of bias due to incorrect responses. Because height tends to be overestimated and weight tends to be underestimated (especially among people with obesity), misclassification of BMI is possible. Second, due to the cross-sectional study design, we could not assess the temporal or causal relationship between obesity and asthma. Third, because this study was conducted using interview data, without anthropometric or clinical data, the mechanism of sex differences in the association between BMI and asthma risk could not be fully investigated. For example, other indices of obesity, such as waist circumference, total fat, visceral fat, and sex hormone levels were not analyzed. Therefore, future studies should involve other assessments, such as anthropometric and clinical assessments.

In conclusion, in a nationally representative sample of Korean adults, the association between BMI and the prevalence of asthma varied between sexes. Underweight in men and obesity in women were associated with an increased risk of asthma. These results suggest that malnutrition in child hood and obesity may be involved in the pathophysiology of asthma.

CONFLICT OF INTEREST STATEMENT

None declared.

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