Combined effect of body mass index and body size perception on metabolic syndrome in South Korea: results of the fifth Korea National Health and Nutrition Examination Surveys (2010-2012)

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Abstract

Background: Body mass index (BMI) has been used as an indirect predictor for the risk of metabolic syndrome. However, there are challenges in evaluating the risk of metabolic syndrome using BMI in certain parts of the world. Therefore, it is worth exploring additional factors that could supplement BMI to predict the risk of metabolic syndrome. In this study, we assessed the combined effect of BMI and perception for predicting metabolic syndrome.

Methods: We used the fifth Korea National Health and Nutrition Examination Surveys (KNHANES V, 2010–12, N = 16,537) in this study. Multivariable logistic regression analysis was performed to examine the association while controlling for potential confounding variables. We also performed an analysis for the combined effect of BMI and perception of body size, and subgroup analysis by age group or moderate physical activity.

Results: Data from 16,537 participants were analyzed in this study (males: 6,978, females: 9,559). Among them, metabolic syndrome was diagnosed in 1,252 (17.9 %) males and 2,445 (25.6 %) females, respectively. The combination of BMI and body size perception had a positive relation with the presence of metabolic syndrome. People who perceived themselves to be overweight for their body size had a higher risk for metabolic syndrome even if they have the same BMI.

Conclusion: Our findings suggest that the combination of body size perception and BMI is useful in predicting the risk of metabolic syndrome. The use of complementary predictors could reduce the risk for inaccurate prediction of metabolic syndrome.

Keywords: Metabolic syndrome, Body mass index, BMI, Perception of body size, Combined effect

Background

South Korea has achieved rapid socioeconomic development since the late 20th century. This fast-paced growth has led to changes in South Koreans’ daily lives, affecting lifestyle and food consumption, and contributing to improved overall health status as South Korea becomes an aging society [1, 2]. However, there has been a concomitant increase in new health problems in South Korea, such as higher rates of chronic disease. According to Statistics Korea, cardiovascular diseases were the fifth leading cause of death in South Korea (50.2 deaths per 100,000 people in 2013) [3].

In the 2013 Organization for Economic Co-operation and Development (OECD) Health at Glance report, South Korea compares poorly with other OECD countries [4]. This problem is expected to be exacerbated by an aging population. To solve those problems, many health care professionals have studied chronic diseases and identified metabolic syndrome as a major cause [5, 6]. Metabolic
syndrome has rapidly increased in South Korea over the past few decades (1998 year: 24.9 %, 2007 year: 31.3 %) [7]. Problems related with metabolic syndrome are expected to continue to increase. Thus, preventing metabolic syndrome is important for managing chronic diseases.

Metabolic syndrome is generally diagnosed by five indicators: waist circumference, triglyceride level, high-density lipoprotein (HDL) cholesterol level, blood pressure, and fasting glucose level. If three indicators (including waist circumference) are met, an individual is diagnosed with metabolic syndrome [8]. Many previous studies identified obesity as the major risk factor of metabolic syndrome. Thus, body mass index (BMI) has been widely used as an indirect predictor for evaluating the risk of metabolic syndrome [9, 10]. However, the use of BMI to predict metabolic syndrome is not necessarily applicable in every country; this simple metric does not consider important factors such as racial/ethnic differences and lifestyle factors. Even in people with the same BMI, the risk of metabolic syndrome may differ, depending on whether they smoke or consume alcohol [11–13]. Therefore, it is worth exploring additional predictors that could supplement BMI to assess the risk of metabolic syndrome; here, we focus on body size perception.

Although many previous studies have assessed the relationship between body size perception and obesity, few have also investigated the incidence of metabolic syndrome in South Korea [14, 15]. Perception of body size is a factor that affects peoples’ lifestyle, including food consumption. Moreover, the risk of metabolic syndrome can be changed by altering one’s lifestyle. In this study, we analyzed the relationship between the incidence of metabolic syndrome and BMI or body size perception, as well as the combined effect of BMI and the body size perception on metabolic syndrome.

Methods

Study population

This study used data from the fifth Korea National Health and Nutrition Examination Surveys (KNHANES V, 2010–12). KNHANES are cross-sectional surveys that have been conducted annually since 1998 by the Korea Centers for Disease Control and Prevention (KCDC) to assess the health and nutritional status of the Korean population. A stratified multistage cluster-sampling design was used to obtain a nationally representative sample. This survey is composed of three parts: Health Interview Survey, Health Examination, and Nutrition Survey. We used data from the Health Interview Survey, Health Examination, and Nutrition Survey. The overall response rates were 81.9 % in 2010, 80.4 % in 2011, and 80.0 % in 2012. A total of 25,967 individuals (8,958 in 2010, 8,491 in 2011, and 8,518 in 2012) completed the survey. Any respondents who did not provide BMI, perceptions of body size, five indicators for the diagnosis of metabolic syndrome, or were under the age of 19 were excluded from the study. We ultimately included 14,773 eligible participants in this study. The KNHANES was openly available in https://knhanes.cdc.go.kr/knhanes/eng/index.do after submitting e-mail address and registering short-form information. These data was approved by the KCDC Institutional Review Board, and all participants provided written informed consent (2010-02CON-21-C, 2011-02CON-06-C, 2012-01-EXP-01-2C).

Variables

The outcome variable in this study was the incidence of metabolic syndrome, which was defined by the International Diabetes Federation (IDF) criteria. It was diagnosed if two of the five indicators (including waist circumference) met the IDF criteria for waist circumference, triglyceride level, HDL cholesterol level, blood pressure, and fasting glucose level.

IDF criteria (metabolic syndrome diagnosed if two or more indicators were present)

1. Waist circumference (male: ≥90 cm and female: ≥80 cm for Asian subjects)
2. Triglycerides level (≥150 mg/dl)
3. HDL cholesterol level (male: <40 mg/dl, female: <50 mg/dl)
4. Blood pressure (systolic: ≥130 mmHg, diastolic: ≥85 mmHg, or treatment of diagnosed hypertension)
5. Fasting glucose level (≥100 mg/dl or type 2 diabetes)

The independent variables of main interest in relation to metabolic syndrome were BMI and body size perception. BMI was calculated as body weight (kg) divided into the squared height (m²). BMI was classified into three groups as follows: ≤22.9, 23.0–24.9, or ≥25. Perception of body size was defined as the answer to the question: “How do you perceive your body size?” The response to this question was classified into: underweight, normal, or overweight.

Other independent variables considered in analysis as potential confounding variables were age, sex, income, educational level, economic activity, marital status, sleep duration, smoking status, alcohol consumption, stress awareness, moderate physical activity, menopause (only female), total energy intake and survey year. Income status was classified as “low”, “mid-low”, “mid-high”, or “high”. Economic activity was defined as “yes” or “no”. Stress awareness was classified as “high”, “moderate”, or “low”. Moderate physical activity was defined as whether respondents performed moderate physical activity for 30 min per session more than 5 times per week. Total energy intake was calculated based on respondent’s self-reported for their usual food consumption.
Statistical analysis
We first examined the distribution of each categorical variable by frequency and percentages and performed $\chi^2$ tests to identify correlation with combination of BMI and body size perception by sex. Next, we performed analysis of variance (ANOVA) for continuous variables as total energy intake to identify correlation with combination of BMI and body size perception and to compare average and standard deviation of variables. In addition, these analyses were also performed to examine differences in each variable according to incidence of metabolic syndrome by sex. Multivariable logistic regression analysis was used to examine the association between BMI or body size perception and metabolic syndrome while controlling for potential confounding variables such as age, sex, income, educational level, economic activity, marital status, sleep duration, smoking status, alcohol consumption, stress awareness, moderate physical activity, menopause (only female), total energy intake, and survey year. We also included menopause status for female respondents. An additional analysis was carried out for the combined effect of BMI and body size perception, as was subgroup analysis by either age group (< vs. ≥65 years) or physical activity. Sampling weights assigned to each participant were applied in the analyses to generalize the sampled data. C-statistics were calculated to examine the predictive values for the logistics model. These values range between 0 (no predictive value) and 1, (perfect predictive value). All statistical analyses were performed using SAS statistical software (Cary, NC) version 9.2.

Results
Data from 14,773 participants were analyzed in this study (males: 5,897, females: 8,876). Tables 1 and 2 shows the association between combination of BMI and body size perception and other covariates by sex. Among them, people who rightly perceived their body size were as follows: males = BMI, ≤22.9, 52.6 %; 23.0–24.9, 64.7 %; ≥25, 78.1 %, and females = BMI, ≤22.9, 26.2 %; 23.0–24.9, 38.0 %; ≥25, 82.5 %. There were statistically significant correlations with combination of BMI and body size perception in both sex (P < .0001). By the results of association between combination of BMI and body size perception and covariates, most of covariates had statistically significant correlations with variables of interest, except to moderate physical activity and survey year in males; moderate physical activity and menopause in females.

Table 3 shows the univariate associations between each variable and metabolic syndrome. Among them, metabolic syndrome was noted in 1,062 (18.0 %) males and 2,304 (26.0 %) females. In both males and females, higher BMI were more frequent in those with metabolic syndrome (males: ≤22.9, 1.5 %; 23.0–24.9, 11.1 %; ≥25, 42.1 % and females: ≤22.9, 5.3 %; 23.0–24.9, 28.5 %; ≥25, 56.4 %). By body size perception, people who responded overweight were more frequently determined to have metabolic syndrome regardless of sex (males: underweight, 2.0 %; normal, 9.9 %; overweight, 37.3 % and females: underweight, 12.7 %; normal, 18.7 %; overweight, 36.7 %). In addition, males who overestimated their body size than BMI were more frequent in those with metabolic syndrome, but females who underestimated their body size were more frequent in those with metabolic syndrome.

The older age group had a higher rate of female metabolic syndrome. Notably, the distribution for metabolic syndrome had an inverse relationship with income in females (low, 42.4 %; mid-low, 28.0 %; mid-high, 20.1 %; high, 16.4 %). Similarly, subjects who were separated, widowed, or divorced were more likely to meet the criteria for metabolic syndrome compared to those with other marital statuses (males: married, 19.2 %; separated/widowed/divorced, 19.9 %; single, 7.1 % and females: married, 23.7 %; separated/widowed/divorced, 43.7 %; single, 5.2 %; Table 3).

Table 4 shows the results of logistic regression analysis for the association between BMI and metabolic syndrome adjusted for covariates by sex. In both males and females, BMI had a positive relationship with metabolic syndrome (males: ≤22.9 = ref, 23.0–24.9 odds ratio [OR]: 22.9, 28.5 %; 23.0, 26.2 %; 23.0–24.9, 38.0 %; ≥25, 82.5 %). There were statistically significant correlations with combination of BMI and body size perception in both sex (P < .0001). By the results of association between combination of BMI and body size perception and covariates, most of covariates had statistically significant correlations with variables of interest, except to moderate physical activity and survey year in males; moderate physical activity and menopause in females.

Table 5 shows the logistic regression analysis results for the association between combined effect of BMI/body size perception and metabolic syndrome adjusted for covariates by sex. The combination of BMI and body size perception had a positive relationship with metabolic syndrome. People who perceived themselves as overweight for their body size had a higher risk for metabolic syndrome, even if they had the same BMI as a person who did not consider themselves overweight. The results of other controlling variables had similar values and trends as the results listed in Table 4 (Table 5).

We also performed subgroup analysis for the combined effect of BMI/body size perception by age group (< vs. ≥65 years) or moderate physical activity to identify possible differences in each group. In the subgroup
| Perception of body size | Males (n = 5,897) | 22.9 (n = 2,340) | 23.0–24.9 (n = 1,520) | ≥25 (n = 2,037) | P-value |
|-------------------------|-------------------|------------------|----------------------|-----------------|---------|
| Variables               | N/Mean %/SD       | N/Mean %/SD      | N/Mean %/SD          | N/Mean %/SD     | N/Mean %/SD      |
| Age (years)             |                   |                  |                      |                 |         |
| 19 ~ 29                 | 119 26.6 91 20.4 14 3.1 | 1 0.2 51 11.4 36 8.1 | 0 0.0 9 2.0 126 28.2 | <.0001 | |
| 30 ~ 39                 | 186 19.9 144 15.4 13 1.4 | 5 0.5 130 13.9 83 8.9 | 1 0.1 37 4.0 336 35.9 |       | |
| 40 ~ 49                 | 178 17.3 136 13.2 15 1.5 | 10 1.0 169 16.4 79 7.7 | 1 0.1 72 7.0 368 35.8 |       | |
| 50 ~ 59                 | 211 18.1 171 14.7 8 0.7 | 13 1.1 239 20.5 123 10.5 | 2 0.2 92 7.9 307 26.3 |       | |
| 60 ~ 69                 | 247 20.4 215 17.8 13 1.1 | 23 1.9 216 17.9 87 7.2 | 10 0.8 110 9.1 289 23.9 |       | |
| ≥70                     | 291 26.2 273 24.6 15 1.4 | 28 2.5 179 16.1 48 4.3 | 8 0.7 105 9.5 164 14.8 |       |         |
| Income                  |                   |                  |                      |                 |         |
| Low                     | 306 27.0 235 20.7 22 1.9 | 31 2.7 181 15.9 57 5.0 | 6 0.5 106 9.3 191 16.8 | <.0001 | |
| Mid-low                 | 364 23.5 273 17.6 20 1.3 | 14 0.9 262 16.9 90 5.8 | 7 0.5 117 7.6 400 25.9 |       | |
| Mid-high                | 295 18.3 283 17.6 18 1.1 | 21 1.3 276 17.2 135 8.4 | 6 0.4 98 6.1 477 29.6 |       | |
| High                    | 267 16.6 239 14.9 18 1.1 | 14 0.9 265 16.5 174 10.8 | 3 0.2 104 6.5 522 32.5 |       | |
| Educational level       |                   |                  |                      |                 |         |
| Below elementary school | 297 24.9 262 22.0 20 1.7 | 34 2.9 205 17.2 59 5.0 | 8 0.7 125 10.5 181 15.2 | <.0001 | |
| Middle school graduated | 158 20.8 116 15.2 5 0.7 | 16 2.1 141 18.5 55 5.2 | 4 0.5 78 10.2 188 24.7 |       | |
| High school graduated   | 426 21.2 352 17.6 23 1.1 | 14 0.7 331 16.5 162 8.1 | 6 0.3 128 6.4 563 28.1 |       | |
| Above University        | 351 18.1 300 15.5 30 1.5 | 16 0.8 307 15.8 180 9.3 | 4 0.2 94 4.8 658 33.9 |       | |
| Economic activity       |                   |                  |                      |                 |         |
| Yes                     | 870 20.0 709 16.3 49 1.1 | 45 1.0 716 16.5 356 8.2 | 13 0.3 314 7.2 1,273 29.3 | <.0001 | |
| No                      | 362 23.3 321 20.7 29 1.9 | 35 2.3 268 17.3 100 6.4 | 9 0.6 111 7.2 317 20.4 |       | |
| Marital status          |                   |                  |                      |                 |         |
| Married                 | 1,012 20.2 840 16.8 62 1.2 | 70 1.4 861 17.2 391 7.8 | 21 0.4 383 7.7 1,361 27.2 | <.0001 | |
| Separated/Bereavement/D | 64 20.9 64 20.9 3 1.0 | 8 2.6 57 18.6 18 5.9 | 1 0.3 27 8.8 64 20.9 |       | |
| Divorced                | 156 26.4 126 21.4 13 2.2 | 2 0.3 66 11.2 47 8.0 | 0 0.0 15 2.5 165 28.0 |       | |
Table 1 Association between combination of BMI and perception of body size and covariates in male (Continued)

| Sleep duration | BMI body mass index | 2010 | 2011 | 2012 | Total energy intake | Total |
|----------------|---------------------|------|------|------|--------------------|-------|
| Less than 6 h  | 497  20.5  408  16.8  35  1.4  36  1.5  401  16.5  206  8.5  14  0.6  167  6.9  660  27.2  0.0025 |
| 7–8 h          | 644  21.0  520  17.0  36  1.2  39  1.3  517  16.9  222  7.2  6  0.2  230  7.5  852  27.8 |
| More than 9 h  | 91    22.4  102  25.1  7   1.7  5   1.2  66   16.2  28   6.9  2   0.5  28   6.9  78   19.2 |
| Smoking status |                     |      |      |      |                   |       |
| Non-smoker/Ex-smoker | 704  19.2  648  17.6  49  1.3  56  1.5  635  17.3  273  7.4  17  0.5  300  8.2  992  27.0  <.0001 |
| Smoker         | 528    23.8  382  17.2  29  1.3  24  1.1  349  15.7  183  8.2  5  0.2  125  5.6  598  26.9 |
| Alcohol consumption |                 |      |      |      |                   |       |
| Never          | 246    23.1  219  20.5  21  2.0  26  2.4  181  17.0  59   5.5  9  0.8  92   8.6  213  20.0  <.0001 |
| Less than 1 time per month | 259  23.4  197  17.8  10  0.9  13  1.2  197  17.8  81   7.3  4  0.4  63   5.7  284  25.6 |
| Less than 3 times per week | 530  18.5  460  16.1  39  1.4  32  1.1  456  15.9  254  8.9  8  0.3  187  6.5  895  31.3 |
| More than 4 times per week | 197  22.9  154  17.9  8   0.9  9   1.0  150  17.4  62   7.2  1  0.1  83   9.6  198  23.0 |
| Stress awareness |                     |      |      |      |                   |       |
| High           | 298    23.4  179  14.1  20  1.6  20  1.6  185  14.5  118  9.3  0  0.0  70   5.5  384  30.1  <.0001 |
| Moderate       | 724    20.8  608  17.4  45  1.3  41  1.2  580  16.6  272  7.8  15  0.4  250  7.2  950  27.3 |
| Low            | 210    18.5  243  21.4  13  1.1  19  1.7  219  19.2  66   5.8  7  0.6  105  9.2  256  22.5 |
| Moderate physical activity |             |      |      |      |                   |       |
| No             | 1,115  20.8  924  17.3  75  1.4  70  1.3  889  16.6  413  7.7  21  0.4  383  7.2  1,460  27.3  0.4056 |
| Yes            | 117    21.4  106  19.4  3   0.5  10  1.8  95   17.4  43   7.9  1  0.2  42   7.7  130  23.8 |
| Survey year    |                     |      |      |      |                   |       |
| 2010           | 396    21.1  313  16.6  32  1.7  28  1.5  311  16.5  145  7.7  4  0.2  148  7.9  504  26.8  0.5417 |
| 2011           | 456    21.4  374  17.6  25  1.2  25  1.2  341  16.0  166  7.8  8  0.4  136  6.4  595  28.0 |
| 2012           | 380    20.1  343  18.1  21  1.1  27  1.4  332  17.6  145  7.7  10  0.5  141  7.5  491  26.0 |
| Total energy intake | 2,312.9 ±906.0 2,252.5 ±903.6 2,269.2 ±1,033.1 2,073.1 ±894.1 2,362.6 ±895.1 2,321.0 ±924.7 1,980.4 ±713.5 2,360.0 ±1,113.0 2,461.1 ±963.6 <.0001 |
| Total          | 1,232  20.9  1,030 17.5  78  1.3  80  1.4  984  16.7  456  7.7  22  0.4  425  7.2  1,590 27.0 |
| BMI | ≤ 22.9 (n = 4,219) | 23.0–24.9 (n = 1,956) | ≥ 25 (n = 2,701) | P-value |
|-----|------------------|----------------------|------------------|---------|
| Perception of body size | Underweight (26.2 %) | Normal (57.6 %) | Overweight (16.3 %) | Underweight (5.7 %) | Normal (38.0 %) | Overweight (56.3 %) | Underweight (2.6 %) | Normal (14.9 %) | Overweight (82.5 %) | Underweight (0.0 %) | Normal (0.0 %) | Overweight (0.0 %) | Underweight (1.0 %) | Normal (1.0 %) | Overweight (0.0 %) |
| Age (years) | | | | | | | | | | | | | | | |
| 19 ~ 29 | 135 | 18.1 | 293 | 39.3 | 116 | 15.5 | 0 | 0.0 | 15 | 2.0 | 67 | 9.0 | 0 | 0.0 | 1 | 0.1 | 119 | 16.0 | <.0001 |
| 30 ~ 39 | 183 | 10.7 | 659 | 38.5 | 265 | 15.5 | 0 | 0.0 | 46 | 2.7 | 231 | 13.5 | 0 | 0.0 | 12 | 0.7 | 314 | 18.4 | |
| 40 ~ 49 | 140 | 8.7 | 515 | 31.9 | 149 | 9.2 | 2 | 0.1 | 75 | 4.6 | 286 | 17.7 | 0 | 0.0 | 18 | 1.1 | 430 | 26.6 | |
| 50 ~ 59 | 163 | 9.1 | 446 | 24.9 | 104 | 5.8 | 6 | 0.3 | 153 | 8.5 | 294 | 16.4 | 6 | 0.3 | 52 | 2.9 | 569 | 31.7 | |
| 60 ~ 69 | 181 | 11.8 | 270 | 17.6 | 31 | 2.0 | 66 | 1.7 | 227 | 14.8 | 156 | 10.2 | 0 | 0.0 | 1.3 | 0.7 | 494 | 32.3 | |
| ≥ 70 | 302 | 20.4 | 246 | 16.6 | 21 | 1.4 | 78 | 5.3 | 227 | 15.3 | 67 | 4.5 | 44 | 3.0 | 194 | 13.1 | 302 | 20.4 | |
| Income | | | | | | | | | | | | | | | | |
| Low | 329 | 17.2 | 364 | 19.0 | 57 | 3.0 | 70 | 3.7 | 240 | 12.5 | 128 | 6.7 | 43 | 2.2 | 195 | 10.2 | 487 | 25.5 | <.0001 |
| Mid-low | 252 | 11.0 | 587 | 25.7 | 164 | 7.2 | 19 | 0.8 | 202 | 8.8 | 297 | 13.0 | 12 | 0.5 | 115 | 5.0 | 640 | 28.0 | |
| Mid-high | 232 | 9.9 | 746 | 31.8 | 236 | 10.1 | 11 | 0.5 | 148 | 6.3 | 287 | 12.2 | 9 | 0.4 | 58 | 2.5 | 618 | 26.4 | |
| High | 291 | 12.5 | 732 | 31.4 | 229 | 9.8 | 12 | 0.5 | 153 | 6.6 | 389 | 16.7 | 6 | 0.3 | 35 | 1.5 | 483 | 20.7 | |
| Educational level | | | | | | | | | | | | | | | | |
| Below elementary school | 455 | 15.4 | 492 | 16.7 | 65 | 2.2 | 103 | 3.5 | 417 | 14.1 | 229 | 7.8 | 63 | 2.1 | 314 | 10.6 | 811 | 27.5 | <.0001 |
| Middle school graduated | 94 | 9.9 | 205 | 21.6 | 38 | 4.0 | 5 | 0.5 | 109 | 11.5 | 131 | 13.8 | 5 | 0.5 | 44 | 4.6 | 316 | 33.4 | |
| High school graduated | 254 | 9.3 | 833 | 30.4 | 300 | 11.0 | 4 | 0.1 | 151 | 5.5 | 420 | 15.3 | 1 | 0.0 | 33 | 1.2 | 741 | 27.1 | |
| Above University graduated | 301 | 13.4 | 899 | 40.1 | 283 | 12.6 | 0 | 0.0 | 66 | 2.9 | 321 | 14.3 | 1 | 0.0 | 12 | 0.5 | 360 | 16.0 | |
| Economic activity | | | | | | | | | | | | | | | | |
| Yes | 493 | 12.0 | 1,166 | 28.3 | 318 | 7.7 | 41 | 1.0 | 320 | 7.8 | 562 | 13.6 | 16 | 0.4 | 154 | 3.7 | 1,048 | 25.4 | <.0001 |
| No | 611 | 12.8 | 1,263 | 26.5 | 368 | 7.7 | 71 | 1.5 | 423 | 8.9 | 539 | 11.3 | 54 | 1.1 | 249 | 5.2 | 1,180 | 24.8 | |
| Marital status | | | | | | | | | | | | | | | | |
| Married | 708 | 10.8 | 1,832 | 28.1 | 540 | 8.3 | 50 | 0.8 | 534 | 8.2 | 894 | 13.7 | 34 | 0.5 | 232 | 3.6 | 1,704 | 26.1 | <.0001 |
| Separated/Bereavement/Divorced | 266 | 16.1 | 319 | 19.3 | 44 | 2.7 | 62 | 3.7 | 198 | 12.0 | 136 | 8.2 | 36 | 2.2 | 170 | 10.3 | 425 | 25.7 | |
| Single | 130 | 18.8 | 278 | 40.2 | 102 | 14.7 | 0 | 0.0 | 11 | 1.6 | 71 | 10.3 | 0 | 0.0 | 1 | 0.1 | 99 | 14.3 | |
Table 2  Association between combination of BMI and perception of body size and covariates in female  (Continued)

| Sleep duration | BMI 12.5 | BMI 9.6 | BMI 12.0 | BMI 39 | BMI 1.0 | BMI 5.9 | BMI 999 | BMI 26.7 | p < 0.0001 |
|----------------|---------|---------|---------|--------|--------|---------|--------|---------|----------|
| Less than 6 h  | 469     | 220     | 625     | 265    | 451    | 105     | 220    | 999     | 26.7     | <0.0001   |
| 7–8 h          | 530     | 328     | 592     | 134    | 0.5    | 149     | 3.4    | 1,061   | 24.0     | 0.0019    |
| More than 9 h  | 105     | 37      | 37      | 1.3    | 7.4    | 8.2     | 8.3    | 1.1     | 4.9      | 168       |
| Smoking status | Non-smoker/Ex-smoker | 1,043 | 1,311 | 398 | 29.6 | 1.6 | 358 | 9.6 | 933 | 24.9 | 220 | 5.9 | 999 | 26.7 | <.0001 |
| Smoker         | 61      | 117     | 29.0    | 44     | 9.9    | 37      | 0.8    | 328     | 7.4      | 134       |
| Alcohol consumption | Never | 526 | 1,172 | 283 | 8.8 | 27 | 0.8 | 37 | 1.6 | 226 | 6.6 | 592 | 13.4 | 23 | 0.5 | 149 | 3.4 | 1,061 | 24.0 | 0.0019 |
| Less than 1 time per month | 367 | 1,370 | 283 | 8.8 | 27 | 0.8 | 37 | 1.6 | 226 | 6.6 | 592 | 13.4 | 23 | 0.5 | 149 | 3.4 | 1,061 | 24.0 | 0.0019 |
| Less than 3 times per week | 188 | 622 | 31.5 | 223 | 11.3 | 15 | 0.8 | 126 | 6.4 | 270 | 13.7 | 4 | 0.2 | 54 | 2.7 | 472 | 23.9 |
| More than 4 times per week | 23 | 41 | 25.3 | 12 | 7.4 | 3 | 1.9 | 19 | 11.7 | 18 | 11.1 | 1 | 0.6 | 7 | 4.3 | 38 | 23.5 |
| Stress awareness | High | 360 | 843 | 242 | 164 | 9 | 346 | 9.9 | 365 | 10.5 | 50 | 1.4 | 235 | 6.8 | 885 | 25.4 | <0.0001 |
| Low            | 186     | 318     | 23.7    | 63     | 4.7    | 31      | 2.3    | 154     | 11.5     | 132       |
| Moderate physical activity | No | 1,027 | 2,253 | 27.6 | 635 | 7.8 | 102 | 1.3 | 679 | 8.3 | 1,012 | 12.4 | 61 | 0.7 | 369 | 4.5 | 2,013 | 24.7 | 0.0755 |
| Yes            | 77      | 176     | 24.3    | 51     | 7.0    | 10      | 1.4    | 64      | 8.8    | 89       |
| Survey year    | 2010    | 330     | 752     | 26.8    | 222    | 7.9    | 38      | 1.4    | 227     | 8.1    | 382     |
| 2011           | 416     | 863     | 27.5    | 238    | 7.6    | 39      | 1.2    | 257     | 8.2    | 360     |
| 2012           | 358     | 814     | 27.7    | 226    | 7.7    | 35      | 1.2    | 259     | 8.8    | 359     |
| Menopause      | Not yet | 464 | 1,499 | 35.8 | 534 | 12.8 | 3 | 0.1 | 152 | 3.6 | 599 | 14.3 | 0 | 0.0 | 34 | 0.8 | 896 | 21.5 |
| Yes            | 640     | 930     | 19.8    | 152    | 3.2    | 109     | 2.3    | 591     | 12.6    | 502     |
| Total energy intake | 1,683.0 ±649.9 | 1,747.8 ±656.5 | 1,724.0 ±699.4 | 1,447.7 ±608.8 | 1,629.2 ±576.5 | 1,683.4 ±654.6 | 1,412.0 ±423.2 | 1,610.2 ±363.0 | 1,694.6 ±650.1 | <0.0001 | 28.3 |
| Total          | 1,104   | 2,429   | 27.4    | 686    | 7.7    | 112     | 1.3    | 743     | 8.4    | 1,101   |

*BMI* body mass index
Table 3 Demographic characteristics by metabolic syndrome (frequency, %)

| Variables                     | Metabolic syndrome (n = 14,773) |                      |                       |                      |                      |                      |
|-------------------------------|---------------------------------|----------------------|-----------------------|----------------------|----------------------|----------------------|
|                               | Males (n = 5,897)               | Females (n = 8,876)  | P-value               | Males (n = 5,897)   | Females (n = 8,876)  | P-value               |
|                               | Yes                             | No                   | N/Mean %/SD           | Yes                  | No                   | N/Mean %/SD           |
| BMI                           |                                 |                      |                       |                      |                      |                      |
| ≤22.9                         | 36                              | 1.5                  | 2,304 98.5            | <.0001               | 222                  | 5.3                  | 3,997 94.7            | <.0001               |
| 23.0–24.9                     | 168                             | 11.1                 | 1,352 88.9            |                      | 558                  | 28.5                 | 1,398 71.5            |                      |
| ≥25                           | 858                             | 42.1                 | 1,179 57.9            |                      | 1,524                | 56.4                 | 1,177 43.6            |                      |
| Perception of body size       |                                 |                      |                       |                      |                      |                      |
| Underweight                   | 27                              | 2.0                  | 1,307 98.0            | <.0001               | 163                  | 12.7                 | 1,123 87.3            | <.0001               |
| Normal                        | 242                             | 9.9                  | 2,197 90.1            |                      | 667                  | 18.7                 | 2,908 81.3            |                      |
| Overweight                    | 793                             | 37.3                 | 1,331 62.7            |                      | 1,474                | 36.7                 | 2,541 63.3            |                      |
| Age (years)                   |                                 |                      |                       |                      |                      |                      |
| 19 ~ 29                       | 23                              | 5.1                  | 424 94.9              | <.0001               | 26                   | 3.5                  | 720 96.5              | <.0001               |
| 30 ~ 39                       | 126                             | 13.5                 | 809 86.5              |                      | 113                  | 6.6                  | 1,597 93.4            |                      |
| 40 ~ 49                       | 186                             | 18.1                 | 842 81.9              |                      | 256                  | 15.9                 | 1,359 84.1            |                      |
| 50 ~ 59                       | 229                             | 19.6                 | 937 80.4              |                      | 486                  | 27.1                 | 1,307 72.9            |                      |
| 60 ~ 69                       | 275                             | 22.7                 | 935 77.3              |                      | 689                  | 45.0                 | 842 55.0              |                      |
| ≥70                           | 223                             | 20.1                 | 888 79.9              |                      | 734                  | 49.6                 | 747 50.4              |                      |
| Income                        |                                 |                      |                       |                      |                      |                      |
| Low                           | 211                             | 18.6                 | 924 81.4              | 0.7869               | 812                  | 42.4                 | 1,101 57.6            | <.0001               |
| Mid-low                       | 275                             | 17.8                 | 1,272 82.2            |                      | 640                  | 28.0                 | 1,648 72.0            |                      |
| Mid-high                      | 279                             | 17.3                 | 1,330 82.7            |                      | 471                  | 20.1                 | 1,874 79.9            |                      |
| High                          | 297                             | 18.5                 | 1,309 81.5            |                      | 381                  | 16.4                 | 1,949 83.6            |                      |
| Educational level             |                                 |                      |                       |                      |                      |                      |
| Below elementary school       | 212                             | 17.8                 | 979 82.2              | <.0001               | 1,363                | 46.2                 | 1,586 53.8            | <.0001               |
| Middle school graduated       | 186                             | 24.4                 | 575 75.6              | <.0001               | 308                  | 32.5                 | 639 67.5              |                      |
| High school graduated         | 337                             | 16.8                 | 1,668 83.2            |                      | 457                  | 16.7                 | 2,280 83.3            |                      |
| Above University graduated    | 327                             | 16.9                 | 1,613 83.1            |                      | 176                  | 7.8                  | 2,067 92.2            |                      |
| Economic activity             |                                 |                      |                       |                      |                      |                      |
| Yes                           | 761                             | 17.5                 | 3,584 82.5            | 0.0980               | 905                  | 22.0                 | 3,213 78.0            | <.0001               |
| No                            | 301                             | 19.4                 | 1,251 80.6            |                      | 1,399                | 29.4                 | 3,359 70.6            |                      |
| Marital status                |                                 |                      |                       |                      |                      |                      |
| Married                       | 959                             | 19.2                 | 4,042 80.8            | <.0001               | 1,544                | 23.7                 | 4,984 76.3            | <.0001               |
Table 3 Demographic characteristics by metabolic syndrome (frequency, %) (Continued)

|                          | 61   | 19.9 | 245  | 80.1 | 724  | 43.7  | 932  | 56.3  |
|--------------------------|------|------|------|------|------|-------|------|-------|
| Separated/Bereavement/Divorced | 42   | 7.1  | 548  | 92.9 | 36   | 5.2   | 656  | 94.8  |
| Sleep duration           |      |      |      |      |      |       |      |       |
| Less than 6 h            | 439  | 18.1 | 1,985| 81.9 | 0.9858| 1,133 | 30.2 | 2,615 | 69.8  | <.0001|
| 7–8 h                    | 550  | 17.9 | 2,516| 82.1 | 973  | 22.0  | 3,456| 78.0  |
| More than 9 h            | 73   | 17.9 | 334  | 82.1 | 198  | 28.3  | 501  | 71.7  |
| Smoking status           |      |      |      |      |      |       |      |       |
| Non-smoker/Ex-smoker     | 683  | 18.6 | 2,991| 81.4 | 0.1356| 2,215 | 26.1 | 6,257 | 73.9  | 0.0653|
| Smoker                   | 379  | 17.0 | 1,844| 83.0 | 89   | 22.0  | 315  | 78.0  |
| Alcohol consumption      |      |      |      |      |      |       |      |       |
| Never                    | 185  | 17.4 | 881  | 82.6 | <.0001| 1,177 | 33.8 | 2,304 | 66.2  | <.0001|
| Less than 1 time per month| 154  | 13.9 | 954  | 86.1 | 721  | 22.1  | 2,538| 77.9  |
| Less than 3 times per week| 520  | 18.2 | 2,341| 81.8 | 365  | 18.5  | 1,609| 81.5  |
| More than 4 times per week| 203  | 23.5 | 659  | 76.5 | 41   | 25.3  | 121  | 74.7  |
| Stress awareness         |      |      |      |      |      |       |      |       |
| High                     | 221  | 17.3 | 1,053| 82.7 | 0.0139| 622   | 25.2 | 1,849 | 74.8  | <.0001|
| Moderate                 | 602  | 17.3 | 2,883| 82.7 | 1,210| 23.9  | 3,852| 76.1  |
| Low                      | 239  | 21.0 | 899  | 79.0 | 472  | 35.1  | 871  | 64.9  |
| Moderate physical activity|     |      |      |      |      |       |      |       |
| No                       | 982  | 18.0 | 4,368| 81.6 | 0.0306| 2,102 | 25.8 | 6,049 | 74.2  | 0.2222|
| Yes                      | 80   | 14.6 | 467  | 85.4 | 202  | 27.9  | 523  | 72.1  |
| Survey year              |      |      |      |      |      |       |      |       |
| 2010                     | 360  | 19.1 | 1,521| 80.9 | 0.0240| 737   | 26.3 | 2,068 | 73.7  | 0.1602|
| 2011                     | 399  | 18.8 | 1,727| 81.2 | 778  | 24.8  | 2,359| 75.2  |
| 2012                     | 303  | 16.0 | 1,587| 84.0 | 789  | 26.9  | 2,145| 73.1  |
| Menopause                |      |      |      |      |      |       |      |       |
| Not yet                  | -    | -    | -    | -    | 417  | 10.0  | 3,766| 90.0  | <.0001|
| Yes                      | -    | -    | -    | -    | 1,887| 40.2  | 2,806| 59.8  |
| Total energy intake      | 2,365.6| ±970.4| 2,346.0| ±935.0| 0.5391| 1,619.0| ±640.1| 1,720.2| ±651.7| <.0001|
| Total                    | 1,062| 18.0 | 4,835| 82.0 | 2,304| 26.0  | 6,572| 74.0  |

BMI body mass index

analysis by age group, it revealed similar relationships of the combined effect of BMI and body size perception in these two groups as were observed in the overall analysis. However, there were some notable findings in nonelderly females. In the overweight group based on BMI, the risk for metabolic syndrome was inversely associated with body size perception (Table 6). In the results of subgroup analysis by moderate physical activity, overweight or obese people based on BMI who underestimated their body size had a higher trend regarding the risk of metabolic syndrome in the moderate physical activity of over 5 times per week group than the other group (data not shown). In the overall multivariable logistic regression, C-statistics were higher in the combination model of BMI and body size perception than when using only BMI models.

Discussion

Due to the rapidly aging population, it is expected that the prevalence of metabolic syndrome will continue to increase in South Korea [16]. It is therefore necessary to design effective strategies to prevent and manage this chronic condition. In recent years, BMI has become a widely used indicator of obesity and indirect predictor for metabolic syndrome. However, it had some limitations that were not overall considered to risk factors for metabolic syndrome [17, 18]. Thus, it is necessary to find complementary predictive factors; we focused on body size perception as a novel predictor for evaluating metabolic syndrome risk. Our results suggest that metabolic syndrome risk was positively related with BMI and were similar to previous studies that examined metabolic syndrome risk factors.
Table 4 Results of multivariable logistic regression analysis for the relationship between BMI and metabolic syndrome

| Variables           | Metabolic syndrome | Males | SD | Females | OR | SD |
|---------------------|--------------------|-------|----|---------|----|----|
|                     |                    | OR    |    | OR      |    |    |
| **BMI**             |                    |       |    |         |    |    |
| ≤22.9               | 1.00               | -     | -  | 1.00    | -  | -  |
| 23.0–24.9           | 9.17               | 5.81  | 14.50 | 6.79 | 5.57 | 8.28 |
| ≥25                 | 71.08              | 46.32 | 109.08 | 27.75 | 22.71 | 33.91 |
| **Age (years)**     |                    |       |    |         |    |    |
| 19 ~ 29             | 1.00               | -     | -  | 1.00    | -  | -  |
| 30 ~ 39             | 2.21               | 1.17  | 4.17 | 2.16 | 1.18 | 3.96 |
| 40 ~ 49             | 3.05               | 1.67  | 5.58 | 4.31 | 2.38 | 7.79 |
| 50 ~ 59             | 4.20               | 2.19  | 8.04 | 5.02 | 2.58 | 9.77 |
| 60 ~ 69             | 5.45               | 2.69  | 11.02 | 8.47 | 4.27 | 16.81 |
| ≥70                 | 7.01               | 3.41  | 14.44 | 12.11 | 6.28 | 23.35 |
| **Income**          |                    |       |    |         |    |    |
| Low                 | 1.00               | -     | -  | 1.00    | -  | -  |
| Mid-low             | 1.18               | 0.84  | 1.66 | 1.07 | 0.87 | 1.33 |
| Mid-high            | 1.12               | 0.80  | 1.58 | 0.98 | 0.77 | 1.23 |
| High                | 1.29               | 0.90  | 1.84 | 0.87 | 0.67 | 1.14 |
| **Educational level**|                   |       |    |         |    |    |
| Below elementary school | 1.00           | -     | -  | 1.00    | -  | -  |
| Middle school graduated   | 1.25             | 0.90  | 1.74 | 0.71 | 0.56 | 0.91 |
| High school graduated | 0.98               | 0.72  | 1.33 | 0.59 | 0.46 | 0.76 |
| Above University graduated | 1.03            | 0.73  | 1.43 | 0.51 | 0.37 | 0.72 |
| **Economic activity** |                   |       |    |         |    |    |
| Yes                 | 1.00               | -     | -  | 1.00    | -  | -  |
| No                  | 1.50               | 1.10  | 2.05 | 1.27 | 1.08 | 1.48 |
| **Marital status**  |                    |       |    |         |    |    |
| Married             | 1.00               | -     | -  | 1.00    | -  | -  |
| Separated/Bereavement/Divorced | 0.81         | 0.52  | 1.26 | 1.10 | 0.92 | 1.31 |
| Single              | 0.85               | 0.53  | 1.38 | 1.26 | 0.69 | 2.28 |
| **Sleep duration**  |                    |       |    |         |    |    |
| Less than 6 h       | 0.91               | 0.75  | 1.10 | 0.85 | 0.72 | 1.00 |
| 7–8 h               | 1.00               | -     | -  | 1.00    | -  | -  |
| More than 9 h       | 0.85               | 0.55  | 1.32 | 1.14 | 0.87 | 1.51 |
| **Smoking status**  |                    |       |    |         |    |    |
| Non-smoker/Ex-smoker| 1.00               | -     | -  | 1.00    | -  | -  |
| Smoker              | 1.31               | 1.04  | 1.64 | 1.37 | 0.92 | 2.06 |
| **Alcohol consumption** |               |       |    |         |    |    |
| Never               | 1.00               | -     | -  | 1.00    | -  | -  |
| Less than 1 time per month | 1.03         | 0.73  | 1.46 | 0.96 | 0.80 | 1.16 |
| Less than 3 times per week | 1.16       | 0.85  | 1.59 | 1.00 | 0.80 | 1.24 |
| More than 4 times per week | 1.92      | 1.36  | 2.72 | 0.84 | 0.49 | 1.43 |
In addition, we observed a combined effect of body size perception and BMI on the risk of metabolic syndrome. Notably, the risk was clearer than that observed using BMI only, and was even observed in subjects with the same BMI but different body perceptions.

In predicting risk for chronic diseases as metabolic syndrome, using only BMI could make some misidentifications because it was calculated by just considering height and weight. If people had same BMI, the risk for metabolic syndrome could be different by major factors consisted of body constitution such as muscle mass and higher body fat [19]. Therefore, using combination of BMI and body size perception would be more helpful in predicting for risk. Based on our results, perception of body size as overweight had higher risk for metabolic syndrome. This is because that perception of body size as overweight could more reflect to risk for metabolic syndrome considering actual body image in same BMI. Perception of body size can help role of complementation of predicting for metabolic syndrome [20]. Therefore, it is suggested that people who perceive their body size as overweight are likely to be at risk of metabolic syndrome. In another point of view, people could respond as overweight for their body size due to their unhealthy behaviors such as unhealthy diet and insufficient physical activity for preventing chronic diseases even if people with same BMI and similar body constitution [21]. Therefore, perception of body size could be indirect indicators for reflecting life styles as well as actual body image.

The same phenomenon was observed when we performed a subgroup analysis by age group that excluded females who were overweight based on BMI and <65 years. This relationship was more positive in males, while the different results in females <65 years may be caused by younger females who did not exhibit health behaviors such as wrong diet and insufficient exercise due to their misperception for their body size despite being overweight or obesity based on BMI. However, in the case of elderly females, they had an effort to manage their health status due to their health concern by advanced age [22]. Based on the results of the subgroup analysis in the moderate physical activity group, people overweight or obese based on BMI tend to exhibit unhealthy behaviors by underestimating their body size and risks of gaining metabolic syndrome as they show moderate physical activity. They may be overconfident, believing in an improvement of their health status by sufficient physical activity, and could take more risky behaviors such as excessive eating. Therefore, providing correct information about preventing metabolic syndrome would be needed.

Although more detailed studies are needed, our findings suggest that inappropriate perception of their health status could be caused to unhealthy behaviors at risky population. This has been described previously; people who are borderline for chronic disease risk do not usually feel that their lives are at risk [23]. Conversely, high-risk populations were much more amenable to health behaviors to modify their risk. It is important to note that males tend to evaluate their own body status more favorably than females. Perception differences can induce people to make lifestyle changes (e.g., food or alcohol consumption, exercise, smoking status, etc.) [15, 24, 25].

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**Table 4** Results of multivariable logistic regression analysis for the relationship between BMI and metabolic syndrome (Continued)

| Stress awareness | 0.99 | 0.70 | 1.38 | 0.90 | 0.70 | 1.17 |
|------------------|------|------|------|------|------|------|
| Moderate         | 0.90 | 0.69 | 1.18 | 0.85 | 0.68 | 1.07 |
| Low              | 1.00 | -    | -    | 1.00 | -    | -    |

| Moderate physical activity | 1.00 | -    | -    | 1.00 | -    | -    |

| Survey year | 0.90 | 0.89 | 1.87 | 1.09 | 0.84 | 1.41 |
|-------------|------|------|------|------|------|------|
| 2010        | 1.00 | -    | -    | 1.00 | -    | -    |
| 2011        | 1.14 | 0.90 | 1.45 | 0.89 | 0.74 | 1.08 |
| 2012        | 0.82 | 0.63 | 1.07 | 1.14 | 0.95 | 1.37 |

| Menopause | 1.00 | 0.99 | 1.01 | 1.01 | 0.99 | 1.02 |
|-----------|------|------|------|------|------|------|
| Not yet   | -    | -    | -    | 1.00 | -    | -    |
| Yes       | -    | -    | -    | 1.45 | 1.09 | 1.92 |

| Total energy intake | 0.855* | 0.876* |
|---------------------|---------|---------|

**BMI** body mass index, **OR** odds ratio, **SD** standard deviation

*P-value for likelihood ratio test < 0.05
Table 5 Results of multivariable logistic regression analysis for the relationship between BMI/body size perception and metabolic syndrome

| Variables                  | Metabolic syndrome |          |          |          |          |
|----------------------------|--------------------|----------|----------|----------|----------|
|                            |                    | Males    | Females  | Males    | Females  |
|                            | OR                 | SD       | OR       | SD       |          |
| Perception of body size    |                    |          |          |          |          |
| ≤22.9                      | Underweight        | 0.41     | 0.19     | 0.53     | 0.35     | 0.79     |
|                            | Normal             | 1.00     | -        | 1.00     | -        | -        |
|                            | Overweight         | 5.38     | 1.42     | 20.36    | 0.98     | 0.59     | 1.65     |
| 23.0–24.9                  | Underweight        | 3.23     | 1.32     | 7.91     | 5.79     | 3.18     | 10.54    |
|                            | Normal             | 5.45     | 2.95     | 10.04    | 5.25     | 3.91     | 7.05     |
|                            | Overweight         | 14.85    | 7.75     | 28.45    | 5.89     | 4.41     | 7.85     |
| ≥25                        | Underweight        | 15.29    | 4.35     | 53.75    | 9.32     | 4.82     | 18.00    |
|                            | Normal             | 25.63    | 13.87    | 47.35    | 18.89    | 12.92    | 27.63    |
|                            | Overweight         | 78.80    | 44.44    | 139.72   | 24.50    | 19.20    | 31.26    |
| Age (years)                |                    |          |          |          |          |
| 19 ~ 29                    | 1.00               | -        | -        | 1.00     | -        | -        |
| 30 ~ 39                    | 2.36               | 1.24     | 4.51     | 2.17     | 1.18     | 3.97     |
| 40 ~ 49                    | 3.45               | 1.88     | 6.30     | 4.31     | 2.38     | 7.80     |
| 50 ~ 59                    | 4.97               | 2.60     | 9.50     | 5.03     | 2.58     | 9.81     |
| 60 ~ 69                    | 6.70               | 3.34     | 13.45    | 8.79     | 4.41     | 17.52    |
| ≥70                        | 9.60               | 4.69     | 19.63    | 13.27    | 6.81     | 25.83    |
| Income                     |                    |          |          |          |          |
| Low                        | 1.00               | -        | -        | 1.00     | -        | -        |
| Mid-low                    | 1.16               | 0.82     | 1.64     | 1.06     | 0.85     | 1.32     |
| Mid-high                   | 1.09               | 0.77     | 1.54     | 0.95     | 0.76     | 1.21     |
| High                       | 1.23               | 0.86     | 1.77     | 0.86     | 0.65     | 1.12     |
| Educational level          |                    |          |          |          |          |
| Below elementary school    | 1.00               | -        | -        | 1.00     | -        | -        |
| Middle school graduated    | 1.15               | 0.82     | 1.63     | 0.69     | 0.54     | 0.88     |
| High school graduated      | 0.86               | 0.62     | 1.18     | 0.57     | 0.44     | 0.73     |
| Above University graduated | 0.84               | 0.60     | 1.19     | 0.49     | 0.35     | 0.69     |
| Economic activity          |                    |          |          |          |          |
| Yes                        | 1.00               | -        | -        | 1.00     | -        | -        |
| No                         | 1.46               | 1.07     | 2.00     | 1.26     | 1.08     | 1.48     |
| Marital status             |                    |          |          |          |          |
| Married                    | 1.00               | -        | -        | 1.00     | -        | -        |
| Separated/Bereavement/Divorced | 0.80          | 0.51     | 1.26     | 1.10     | 0.92     | 1.32     |
| Single                     | 0.85               | 0.52     | 1.38     | 1.25     | 0.69     | 2.27     |
| Sleep duration             |                    |          |          |          |          |
| Less than 6 h              | 0.88               | 0.72     | 1.08     | 0.85     | 0.72     | 1.00     |
| 7–8 h                      | 1.00               | -        | -        | 1.00     | -        | -        |
| More than 9 h              | 0.83               | 0.52     | 1.30     | 1.16     | 0.87     | 1.53     |
| Smoking status             |                    |          |          |          |          |
| Non-smoker/Ex-smoker       | 1.00               | -        | -        | 1.00     | -        | -        |
| Smoker                     | 1.31               | 1.05     | 1.65     | 1.37     | 0.91     | 2.06     |
In accordance with this, we found that South Korean subjects with the same BMI exhibited different behaviors based on their body size perception; therefore, predicting metabolic syndrome risk solely based on BMI did not take different behaviors into account [26, 27]. Thus, our findings suggest that the combination of body size perception and BMI could be more useful in predicting the risk of metabolic syndrome than BMI alone. The use of complementary predictors could improve prediction and prognostication.

This study has several strengths compared to previous investigations. First, we used nationally representative data, so our study results are representative and generalizeable to South Korea citizens. Such data are especially helpful in establishing evidence-based health policies. To our knowledge, this is the first attempt to study the relationship between the combined effect of BMI/body size perception and metabolic syndrome in South Korea, despite numerous issues regarding the management of these health issues in the country. Therefore, our findings should be helpful in identifying ways to address these critical issues.

Our study also has some limitations. First, due to the cross-sectional nature of the KNHANES, it is not possible to identify causal relationships. Other issues must be considered to more accurately measure the relationship between the combined effect of BMI/body size perception and metabolic syndrome. Next, our findings included high OR values, not general OR values. Further studies are needed to confirm our findings, which show a combined effect for metabolic syndrome in relatively small study populations (after stratification). Nevertheless, the overall trends of our findings have serious implications for the management of metabolic syndrome. Third, body size perception was measured by the subjects’ answers to the question: “How do you perceive your body size?” The response could have been incorrectly perceived by researchers and is not a truly scientific measurement. Finally, our analysis did not include important details such as respondent food consumption. Thus, multiple variables that are not a major factor of metabolic syndrome were not considered in our findings.

Despite these limitations, our findings suggest that the combined effect of BMI and body size perception can be used to predict the presence of metabolic syndrome. Based on these findings, it is important for health policy makers to identify solutions for controlling metabolic syndrome.
| Perception of body size | Metabolic syndrome |  |  |
|------------------------|---------------------|---|---|
|                        | Males               | Females           |
|                        | Less than 64 years  | More than 65 years | Less than 64 years | More than 65 years |
| BMI                    | OR      | SD | OR      | SD | OR      | SD | OR      | SD |
| ≤22.9                  | 1.00    | -  | 1.00    | -  | 1.00    | -  | 1.00    | -  |
| 23.0–24.9              | 9.31    | 4.87 | 17.12 | 6.00 | 19.21 | 10.74 | 12.88 | 5.32 |
| ≥25                    | 74.63   | 42.15 | 132.16 | 30.98 | 97.88 | 55.07 | 54.15 | 15.78 |
| ≤22.9                  | 0.39    | 0.12 | 1.28 | 0.41 | 1.32 | 0.47 | 1.13 | 0.40 |
| Normal                 | 1.00    | -  | 1.00 | -  | 1.00 | -  | 1.00 | -  |
| Overweight             | 5.29    | 1.04 | 26.88 | 2.46 | 14.13 | 4.81 | 2.20 | 1.25 |
| 23.0–24.9              | 0.97    | 0.17 | 5.73 | 6.10 | 18.95 | 1.15 | 0.60 | 1.25 |
| Normal                 | 4.81    | 1.95 | 11.89 | 6.97 | 14.46 | 7.02 | 11.27 | 4.44 |
| Overweight             | 15.32   | 6.06 | 38.74 | 12.20 | 31.22 | 7.96 | 5.13 | 4.44 |
| 23.0–24.9              | 23.41   | 3.74 | 146.52 | 7.82 | 44.43 | 10.18 | 45.72 | 6.52 |
| Normal                 | 26.09   | 10.87 | 62.63 | 25.64 | 56.64 | 24.44 | 53.94 | 22.44 |
| Overweight             | 76.93   | 33.14 | 173.96 | 59.06 | 123.50 | 36.60 | 14.73 | 6.97 |
| C-statistics           | Only BMI Model  | 0.846* | 0.856* | 0.878* | 0.784* |
|                        | Combination Model | 0.858* | 0.864* | 0.882* | 0.791* |

*P-value for likelihood ratio test <0.05
However, further studies of those issues are needed to establish an effective strategy.

Conclusion
The combined effects of body size perception and BMI affect the risk for metabolic syndrome in individuals with the same BMI. Our findings suggest that both variables should be used in predicting the risk of disease to reduce risk of inaccurate predictions.

Abbreviations
OECD: Organization for Economic Co-operation and Development; HDL: High-density lipoprotein; BMI: Body mass index; KNHANES: Korea National Health and Nutrition Examination Surveys; KCDC: Korea Centers for Disease Control and Prevention; IDF: International Diabetes Federation; OR: Odds ratio; SD: Standard deviation.

Competing interests
The authors declare that they have no competing interests.

Authors’ contributions
SHY and KTH led the design and conception of the study, performed the data analysis, and wrote the manuscript. SJK, TYS, BJ, and ECP participated in the study design and provided intellectual input for the development of the manuscript. WRK provided re-editing for our manuscript to improve quality of scientific writing. ECP helped draft this manuscript. All authors read and approved the final manuscript.

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