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## Sex-specific interactions between education and income in relation to obesity: evidence from South Korea

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4 **Sex-specific interactions between education and income**  
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## 1 ABSTRACT

### 3 Objectives

4 To examine whether a well-known, negative association between socioeconomic status and  
5 obesity in developed countries remains valid, when a full set of interaction effects are  
6 included.

### 7 Design

8 A cross-sectional study. Education and income levels were chosen as socioeconomic status  
9 indicators. Socio-demographics, lifestyles and medical conditions were used as covariates in  
10 multivariate logistic regression models. Adjusted odds ratios and predicted probabilities of  
11 obesity were computed and adjusted for a complex survey design.

### 12 Setting

13 Data were obtained from a secondary source, the Fifth Korea National Health and Nutrition  
14 Examination Survey (2010-2012).

### 15 Participants

16 The sample included 7,337 male and 9,908 female participants aged 19 years or older.

### 17 Outcome measure

18 Obesity defined as body mass index of 25 or more, according to a guideline for Asians.

### 19 Results

20 In models with no interaction effect, only education showed a significant association with  
21 obesity in men, but in women both income and education were significant. In models with  
22 interaction effects, however, income was significant in men but education was significant in  
23 women. An interaction effect between income and education was significant in men but not

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4 24 in women. Participants having the highest predicted probability of obesity over educational  
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6 25 and income levels differed between the two models, and between men and women. Though  
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8 26 caution is necessary, the findings of the predicted probabilities of obesity suggest that a  
9  
10 27 policy providing all men with the highest level of formal education would, counter-intuitively,  
11  
12 28 raise their rate of obesity by as much as 26%.

### 29 **Conclusions**

30 The well-known association between socioeconomic status and obesity may not be valid  
31 when interaction effects are included. Ignoring these effects and their sex differences may  
32 result in targeting the wrong population for reducing obesity prevalence and its resultant  
33 socioeconomic gradients. Further research is needed to examine whether these findings are  
34 valid in other sociocultural settings.

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## 36 Article summary

### 37 Strengths and limitations of this study

- 38 1. This is the first study to investigate the association of socioeconomic status with  
39 obesity while fully considering both main effects and interaction effects.
- 40 2. This study analyzed data from sample of nationally representative South Korean  
41 adults, providing abundant information about anthropometric measures, socio-  
42 demographic characteristics, lifestyle behaviors, and medical conditions.
- 43 3. This study shows by means of a quantified prediction what would happen if policies  
44 to reduce obesity prevalence did not consider complex interactions among  
45 characteristics of individuals.
- 46 4. The cross-sectional study design used in this study precludes causal inferences about  
47 the relationship between socioeconomic status and obesity.

## 1 INTRODUCTION

2  
3 Numerous studies have investigated various factors related to obesity and have found  
4 associations between socioeconomic status and obesity: socioeconomic status and obesity are  
5 negatively correlated in both men and women in developed countries, although this is more  
6 consistent in women than in men.<sup>1-3</sup> However, because empirical studies of obesity have  
7 ignored the interaction effects among various characteristics, these studies have failed to  
8 detect sophisticated associations between different levels of socioeconomic status in relation  
9 to obesity, and to explain differences among different population groups regarding  
10 mechanisms through which socioeconomic status becomes associated with obesity.

11 For example, when the interaction effects among various characteristics are  
12 considered, such studies have not answered the question as to whether the above-mentioned,  
13 well-known associations between socioeconomic status and obesity remain valid. Moreover,  
14 they have seldom explored why an socioeconomic status indicator sometimes interacts with  
15 another socioeconomic status indicator with regard to obesity, and whether interaction differs  
16 by sex; whether the likelihood of being obese with regard to some levels of socioeconomic  
17 status remains the same before and after consideration of the interaction effects; and whether  
18 government can reduce the prevalence of obesity and change the socioeconomic gradient in  
19 the prevalence of this condition by providing all individuals with the highest level of  
20 socioeconomic status possible.

21 Attempting to fill the gap between previous findings and the unanswered questions,  
22 this study chose education and income levels as socioeconomic status indicators because  
23 these two indicators complement each other: educational level is established in early  
24 adulthood and tends to remain unchanged later in life, while income level may change

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4 25 throughout adult life. In particular, this study used data from South Korea, which has  
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6 26 industrialized rapidly and is now categorized as one of the ten largest advanced economies in  
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8 27 the world.<sup>4</sup> Nevertheless, South Korea is still noted for pronounced sex inequality almost  
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10 28 everywhere, especially in labor markets.<sup>5 6</sup>

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12 This study considered two models for each sex: one included only the main-effect  
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14 30 term of each variable, and the other included the two-way interaction-effect terms between  
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16 31 variables, as well as the main-effect term of each variable. Considering the complex survey  
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18 32 design, this study used multivariate logistic regression analyses to compute the odds ratios of  
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20 33 obesity and to predict the probability that a man or woman would be obese if he or she had a  
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22 34 particular set of education and income levels.  
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## 28 36 **MATERIALS AND METHODS**

### 29 37 **Data source and study sample**

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31 38 This study was based on the Fifth Korea National Health and Nutrition Examination Survey  
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33 39 (KNHANES V), 2010–2012, which used a stratified multistage clustered probability  
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35 40 sampling design to collect data on the non-institutionalized, civilian population of South  
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37 41 Korea on behalf of the Korean Centers for Disease Control and Prevention.<sup>7</sup> This research  
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39 42 was composed of a health interview and a nutrition survey conducted at participants' homes  
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41 43 as well a physical examination by conducted by physicians at designated examination  
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43 44 centers. Detailed information about the survey design and characteristics is available at  
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45 45 <https://knhanes.cdc.go.kr>.

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47 46 For KNHANES V, this study accessed data from a pool of 25,534 individuals (8,958  
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49 47 in 2010, 8,518 in 2011, and 8,058 in 2012). Of this group, 24,173 had participated in the  
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4 48 interviews, and 18,571 individuals aged 19 years or older received physical examinations. A  
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6 49 total of 17,245 (92.86%) participants (7,337 men, 9,908 women) were included in this study  
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9 50 because they had the required information in their files. The ethical review board of the  
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11 51 educational institution where the research was conducted approved this study.  
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### 15 53 **Measures and variables**

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18 54 The obesity status of each participant was determined anthropometrically using data from the  
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20 55 physical examination. Height was measured using a portable stadiometer, and body weight  
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22 56 was measured using a calibrated balance-beam scale, and the body mass index was calculated  
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24 57 from these height and weight measurements. According to the guidelines proposed by the  
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26 58 World Health Organization indicating that Asians have a lower average body mass index,<sup>8</sup>  
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28 59 this study defined general obesity as a body mass index of at least 25.  
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31 60 Levels of education and income were chosen as socioeconomic status indicators.  
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33 61 Education was defined as the highest level of formal education completed as of the date of  
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35 62 the interview. This study categorized education into four levels: elementary school or less,  
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37 63 junior high school, senior high school, and college or more. For income, this study used an  
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39 64 equivalized monthly household income calculation ( $[\text{monthly overall household income}]$   
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41 65  $[\text{household size}]^{-0.5}$ ) and divided participants into four quartiles.  
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44 66 Nine sociodemographic characteristics, including sex, were incorporated as  
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46 67 covariates. Age was treated as a continuous variable, and marital status was categorized into  
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48 68 married, formerly married, and never married. Residential area was divided into metropolitan  
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50 69 urban area, non-metropolitan urban area, and rural area. Occupation was grouped into  
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52 70 unemployed, office worker, and manual worker. Housing status was coded in terms of  
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4 71 whether a participant was a renter or a home owner. Participants' status with regard to the  
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6 72 universal health insurance program was divided according to whether they were enrolled in  
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8 73 National Health Insurance for regular-income individuals or Medical Care Aid for low-  
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10 74 income individuals. Status with regard to private health insurance was coded according to  
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12 75 whether participants had insurance of this type. Survey year was added to control for any  
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14 76 fixed time effect.  
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18 This study also incorporated ten characteristics about lifestyle and medical  
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20 78 conditions. Participants were grouped in terms of the following categories: 1)  
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22 79 smoking, 2) excessive alcohol consumption (at high risk due to drinking according to  
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24 80 the sex-specific guidelines of the World Health Organization),<sup>9</sup> 3) routinely  
25  
26 81 exercising (physical activity as defined as participation in moderate or vigorous  
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28 82 exercise for a respective frequency and duration),<sup>10</sup> 4) daily sleep duration (sleeping  
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30 83 less than 7 h per day was defined as sleeping for a short duration),<sup>11</sup> 5) daily energy  
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32 84 intake (moderate energy intake was defined as total energy intake within 1.25× of  
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34 85 participants' estimated daily energy requirement),<sup>12</sup> 6) self-perceived stress, 7) self-  
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36 86 perceived health, 8) hypertension, 9) dyslipidemia, and 10) diabetes. The presence of  
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38 87 the last three chronic diseases was determined by a prior physician diagnosis at the  
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40 88 pre-surgery interview.  
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#### 46 **Analytic procedures**

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48 91 A six-fold analysis was performed. First, this study tested differences in the distributions of  
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50 92 variables among men and women using the *t*-test for continuous variables and the  $\chi^2$  test for  
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52 93 categorical variables. Second, this study tested the association of each variable with obesity  
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54 94 by sex using the  $\chi^2$  test. Third, sex interaction effects were examined, for which simple

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4 95 logistic regression models were constructed with main effects for sex and the variable of  
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6 96 interest as well as the interaction effects of the two variables. Due to the results, the  
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9 97 remaining analyses were stratified by sex.

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11 98 Fourth, to fit multivariate logistic regression models, this study continued to re-  
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13 99 categorize each of the variables and defined each variable's reference category differently  
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15 100 until no strong multicollinearity was found for the main-effect models and no evidence of a  
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17 101 lack of goodness-of-fit was found in each model. The values for the variance inflation factor  
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19 102 were less than 3.65, and p-values based on the Hosmer–Lemeshow statistic were higher than  
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21 103 0.26.

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24 104 Fifth, this study estimated the adjusted odds ratios (ORs) of obesity and their 95%  
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26 105 confidence intervals (CIs) after fully adjusting for covariates. Two models were considered  
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28 106 for each sex: Model 1 included only the main-effect term of every variable, and Model 2  
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30 107 included the main-effect terms for each variable as well the two-way interaction-effect terms  
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32 108 between variables.

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35 109 Finally, to assess the association of each level of a socioeconomic status indicator  
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37 110 with obesity and to compare these associations across categories for both socioeconomic  
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39 111 status indicators, this study predicted the probability of a participant being obese (and its 95%  
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41 112 confidence intervals) if he or she had a certain educational and income level. These  
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43 113 probabilities, which were calculated by sex, denote the average of all participants'  
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45 114 probabilities if each participant belonged to a certain education and income level, while  
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47 115 maintaining participant characteristics for the other variables constant.

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50 116 All analyses and tests were conducted considering the sampling design of the survey.  
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52 117 However, for convenience, the descriptive statistics are shown as unweighted. P-values <  
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54 118 0.05 were considered statistically significance. The SAS 9.2 software (SAS Institute, Cary,

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4 119 NC, USA) and STATA 12 software (StataCorp, College Station, TX, USA) were used to  
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6 120 perform all statistical analyses.  
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## 10 122 **RESULTS**

### 11 123 **Descriptive statistics**

12 124 The rate of obesity was significantly higher in men (34.96%) than in women (29.67%), as  
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16 125 indicated in the significantly higher body mass index in men than women (Table 1). All  
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18 126 characteristics differed significantly by sex except residential area, housing status, enrollment  
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22 127 in a private health insurance plan, survey year, daily sleep duration, and diabetes status.  
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129 **Table 1** Sample characteristics and their associations with obesity by sex: the Fifth Korea National Health and Nutrition Examination Survey  
 130 (KNHANES V), 2010-2012, South Korea

|                                       | Distribution, N (%) |               |          | Obesity, % |         |          |
|---------------------------------------|---------------------|---------------|----------|------------|---------|----------|
|                                       | Men                 | Women         | p Value† | Men        | Women   | p Value‡ |
| Body mass index, kg m <sup>-2</sup> * | 23.97 (3.13)        | 23.43 (3.55)  | <0.001   |            |         |          |
| Obesity                               | 2565 (34.96)        | 2940 (29.67)  | <0.001   |            |         |          |
| Age, years*                           | 50.79 (16.39)       | 50.48 (16.59) | <0.001   | 35.08‡     | 34.68‡  | <0.001   |
| Marital status                        |                     |               | <0.001   | <0.001§    | <0.001§ | <0.001   |
| Married                               | 5848 (79.71)        | 6887 (69.51)  |          | 36.01      | 30.54   |          |
| Formerly married                      | 339 (4.62)          | 1803 (18.20)  |          | 30.09      | 37.38   |          |
| Never-married                         | 1150 (15.67)        | 1218 (12.29)  |          | 31.04      | 13.38   |          |
| Residential area                      |                     |               | 0.446    | 0.259§     | <0.001§ | <0.001   |
| Metro urban                           | 3240 (44.16)        | 4404 (44.45)  |          | 35.15      | 27.00   |          |
| Non-metro urban                       | 2523 (34.39)        | 3471 (35.03)  |          | 36.62      | 29.16   |          |
| Rural                                 | 1574 (21.45)        | 2033 (20.52)  |          | 31.89      | 36.35   |          |
| Education                             |                     |               | <0.001   | <0.001§    | <0.001§ | <0.001   |
| Elementary school or less             | 1294 (17.64)        | 3168 (31.97)  |          | 26.58      | 40.18   |          |
| Junior high school                    | 867 (11.82)         | 1024 (10.34)  |          | 36.10      | 38.57   |          |
| Senior high school                    | 2617 (35.67)        | 3136 (31.65)  |          | 34.47      | 27.10   |          |
| College or more                       | 2559 (34.87)        | 2580 (26.04)  |          | 39.31      | 16.36   |          |
| Income, quartiles                     |                     |               | <0.001   | 0.002§     | <0.001§ | <0.001   |
| Lowest                                | 1694 (23.09)        | 2641 (26.66)  |          | 28.39      | 36.80   |          |
| 2nd lowest                            | 1924 (26.22)        | 2514 (25.37)  |          | 36.49      | 31.74   |          |
| 3rd lowest                            | 1739 (23.70)        | 2177 (21.97)  |          | 34.91      | 27.97   |          |

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| 4  |                            |              |              |        |         |         |        |  |
| 5  | Highest                    | 1980 (26.99) | 2576 (26.00) |        | 39.14   | 21.78   |        |  |
| 6  | Occupation                 |              |              | <0.001 | <0.001§ | <0.001§ | <0.001 |  |
| 7  | Unemployed                 | 1878 (25.60) | 5208 (52.56) |        | 28.65   | 31.07   |        |  |
| 8  | Office worker              | 1965 (26.78) | 1586 (16.01) |        | 42.09   | 17.47   |        |  |
| 9  | Manual worker              | 3494 (47.62) | 3114 (31.43) |        | 34.34   | 33.56   |        |  |
| 10 | Housing status             |              |              | 0.158  | 0.945§  | 0.843§  | 0.838  |  |
| 11 | Renter                     | 5606 (76.41) | 7280 (73.48) |        | 35.07   | 29.52   |        |  |
| 12 | Home owner                 | 1731 (23.59) | 2628 (26.52) |        | 34.60   | 30.10   |        |  |
| 13 | Universal health insurance |              |              | <0.001 | 0.020§  | 0.004§  | <0.001 |  |
| 14 | National Health Insurance  | 7204 (98.19) | 9609 (96.98) |        | 35.15   | 29.36   |        |  |
| 15 | Medical Care Aid           | 133 (1.81)   | 299 (3.02)   |        | 24.81   | 39.80   |        |  |
| 16 | Private health insurance   |              |              | 0.181  | <0.001§ | <0.001§ | <0.001 |  |
| 17 | Non-holder                 | 2258 (30.78) | 2898 (29.25) |        | 29.27   | 34.89   |        |  |
| 18 | Holder                     | 5079 (69.22) | 7010 (70.75) |        | 37.49   | 27.52   |        |  |
| 19 | Survey year                |              |              | 0.831  | 0.695§  | 0.133§  | 0.162  |  |
| 20 | 2010                       | 2592 (35.33) | 3364 (33.95) |        | 35.22   | 28.27   |        |  |
| 21 | 2011                       | 2494 (33.99) | 3380 (34.12) |        | 34.60   | 30.36   |        |  |
| 22 | 2012                       | 2251 (30.68) | 3164 (31.93) |        | 35.05   | 30.44   |        |  |
| 23 | Current smoking status     |              |              | <0.001 | 0.375§  | 0.936§  | 0.729  |  |
| 24 | Non-smoker                 | 4336 (59.10) | 9359 (94.46) |        | 36.12   | 29.82   |        |  |
| 25 | Smoker                     | 3001 (40.90) | 549 (5.54)   |        | 33.29   | 27.14   |        |  |
| 26 | Alcohol consumption        |              |              | <0.001 | <0.001§ | 0.064§  | <0.001 |  |
| 27 | Not excessive              | 4950 (67.47) | 8689 (87.70) |        | 31.49   | 30.08   |        |  |
| 28 | Excessive                  | 2387 (32.53) | 1219 (12.30) |        | 42.14   | 26.74   |        |  |
| 29 | Routine physical exercise  |              |              | <0.001 | 0.838§  | <0.001§ | 0.012  |  |

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| 5  | Physically active      | 1552 (21.15) | 1620 (16.35) |        | 35.63   | 32.84   |        |
| 6  | Physically inactive    | 5785 (78.85) | 8288 (83.65) |        | 34.78   | 29.05   |        |
| 7  |                        |              |              |        |         |         |        |
| 8  | Daily sleep duration   |              |              | 0.992  | 0.150§  | <0.001§ | 0.007  |
| 9  | Non-short              | 4291 (58.48) | 5717 (57.70) |        | 34.21   | 27.41   |        |
| 10 | Short                  | 3046 (41.52) | 4191 (42.30) |        | 36.01   | 32.76   |        |
| 11 |                        |              |              |        |         |         |        |
| 12 | Daily energy intake    |              |              | <0.001 | 0.818§  | <0.001§ | <0.001 |
| 13 | Not moderate           | 5859 (79.86) | 8306 (83.83) |        | 34.85   | 27.97   |        |
| 14 | Moderate               | 1478 (20.14) | 1602 (16.17) |        | 35.39   | 38.51   |        |
| 15 |                        |              |              |        |         |         |        |
| 16 | Self-perceived stress  |              |              | <0.001 | 0.969§  | 0.031§  | 0.236  |
| 17 | Not very high          | 7087 (96.59) | 9421 (95.08) |        | 35.05   | 29.49   |        |
| 18 | Very high              | 250 (3.41)   | 487 (4.92)   |        | 32.40   | 33.26   |        |
| 19 |                        |              |              |        |         |         |        |
| 20 | Self-perceived health  |              |              | <0.001 | 0.362§  | <0.001§ | 0.002  |
| 21 | Not very bad           | 7159 (97.57) | 9467 (95.55) |        | 35.23   | 29.08   |        |
| 22 | Very bad               | 178 (2.43)   | 441 (4.45)   |        | 24.16   | 42.40   |        |
| 23 |                        |              |              |        |         |         |        |
| 24 | Hypertension           |              |              | <0.001 | <0.001§ | <0.001§ | <0.001 |
| 25 | No                     | 5764 (78.56) | 7713 (77.85) |        | 32.62   | 24.32   |        |
| 26 | Yes                    | 1573 (21.44) | 2195 (22.15) |        | 43.55   | 48.47   |        |
| 27 |                        |              |              |        |         |         |        |
| 28 | Dyslipidemia           |              |              | <0.001 | <0.001§ | <0.001§ | 0.137  |
| 29 | No                     | 6859 (93.49) | 9065 (91.49) |        | 33.87   | 27.80   |        |
| 30 | Yes                    | 478 (6.51)   | 843 (8.51)   |        | 50.63   | 49.82   |        |
| 31 |                        |              |              |        |         |         |        |
| 32 | Diabetes               |              |              | 0.099  | 0.858§  | <0.001§ | <0.001 |
| 33 | No                     | 6661 (90.79) | 9219 (93.05) |        | 34.84   | 28.13   |        |
| 34 | Yes                    | 676 (9.21)   | 689 (6.95)   |        | 36.09   | 50.36   |        |
| 35 |                        |              |              |        |         |         |        |
| 36 | Number of participants | 7337         | 9908         |        | 7337    | 9908    |        |

N, number; All P-values were estimated by considering a stratified cluster sampling design.

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\*Mean (standard deviation).

†P-value was estimated by using the t-test for continuous variables and  $\chi^2$  tests for categorical variables.

‡For the continuous age variable, the proportion of obesity was obtained from people aged 50-59 years to which median age for each sex belonged.

§P-value was estimated by  $\chi^2$  tests for each sex.

¶P-value was estimated from the interaction effects terms between sex and each characteristic by using the logistic analysis.

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4 132 **Characteristics associated with obesity and sex differences**

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6 133 Among men, the rate of obesity was significantly higher in participants who were married,  
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8 134 had at least a college education, had incomes in the highest quartile, had an office job, were  
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10 135 National Health Insurance beneficiaries, had a private health insurance plan, consumed  
11  
12 136 excessive alcohol, suffered from hypertension, and had dyslipidemia (Table 1).

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15 137 Among women, a significantly higher rate of obesity was found in participants who  
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17 138 were formerly married, lived in a rural area, did not go beyond elementary school, had  
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19 139 incomes in the lowest quartile, were manual workers, were Medical Care Aid beneficiaries,  
20  
21 140 had no private health insurance plan, were physically active, lacked adequate sleep, had  
22  
23 141 moderate energy intake, reported very high levels of stress, had very poor self-perceived  
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25 142 health, suffered from hypertension, had dyslipidemia, and were diabetic. The rate of obesity  
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27 143 differed significantly by sex with regard to all variables except housing status, survey year,  
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29 144 current smoking status, self-perceived stress, and suffering from dyslipidemia.  
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35 146 **Adjusted associations of obesity with education and income**

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37 147 Among men, according to the model with only main-effect terms (Model 1), the OR of  
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39 148 obesity was 1.41 (95% CI = 1.12–1.77) in those with at least a college education compared  
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41 149 with their counterparts who did not go beyond elementary school (Table 2). Conversely,  
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43 150 according to the model with interaction-effect terms (Model 2), the OR was 0.05 (95% CI =  
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45 151 0.01–0.32) among those with incomes in the highest quartile compared with those with  
46  
47 152 incomes in the lowest quartile. Education alone was not significant. In terms of their  
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49 153 association with obesity, education and income were found to interact with each other, as five  
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51 154 combinations of educational and income levels were significant compared with their  
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53 155 respective reference combinations.  
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156 **Table 2** Adjusted associations of education and income with obesity by sex: the Fifth Korea National Health and Nutrition Examination  
 157 Survey (KNHANES V), 2010-2012, South Korea

|                                  | Men (N=7337)       |                    | Women (N=9908)      |                    |
|----------------------------------|--------------------|--------------------|---------------------|--------------------|
|                                  | Model 1†           | Model 2‡           | Model 1†            | Model 2‡           |
|                                  | OR (95% CI)        | OR (95% CI)        | OR (95% CI)         | OR (95% CI)        |
| <b>Main effects</b>              |                    |                    |                     |                    |
| Education                        |                    |                    |                     |                    |
| Elementary school or less (EDU1) | 1.00               | 1.00               | 1.00                | 1.00               |
| Junior high school (EDU2)        | 1.41** (1.10-1.82) | 0.61 (0.06-6.56)   | 1.19 (0.98-1.44)    | 0.16* (0.03-0.89)  |
| Senior high school (EDU3)        | 1.27* (1.03-1.58)  | 0.57 (0.08-4.25)   | 0.89 (0.72-1.09)    | 0.13** (0.03-0.58) |
| College or more (EDU4)           | 1.41** (1.12-1.77) | 1.45 (0.16-13.04)  | 0.59*** (0.46-0.75) | 0.13* (0.02-0.89)  |
| Income, quartiles                |                    |                    |                     |                    |
| Lowest (INC1)                    | 1.00               | 1.00               | 1.00                | 1.00               |
| 2nd lowest (INC2)                | 1.13 (0.91-1.39)   | 0.11* (0.02-0.64)  | 0.99 (0.84-1.16)    | 1.13 (0.26-4.98)   |
| 3rd lowest (INC3)                | 1.01 (0.81-1.28)   | 0.18 (0.03-1.11)   | 0.93 (0.77-1.11)    | 1.16 (0.22-6.20)   |
| Highest (INC4)                   | 1.10 (0.87-1.39)   | 0.05** (0.01-0.32) | 0.73** (0.60-0.89)  | 1.58 (0.30-8.38)   |
| <b>Interaction effects</b>       |                    |                    |                     |                    |
| Education x Income               |                    |                    |                     |                    |
| EDU2 x INC2                      |                    | 1.91 (0.91-4.04)   |                     | 0.77 (0.44-1.33)   |
| EDU2 x INC3                      |                    | 1.88 (0.81-4.34)   |                     | 1.11 (0.60-2.06)   |

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|-------------------------------|-------------------|------------------|-------|-------|
| EDU2 x INC4                   | 1.72 (0.65-4.59)  | 0.51 (0.26-1.01) |       |       |
| EDU3 x INC2                   | 2.30* (1.17-4.52) | 1.58 (0.90-2.75) |       |       |
| EDU3 x INC3                   | 2.17* (1.05-4.47) | 1.34 (0.73-2.47) |       |       |
| EDU3 x INC4                   | 1.52 (0.67-3.44)  | 1.23 (0.67-2.24) |       |       |
| EDU4 x INC2                   | 2.74* (1.14-6.56) | 1.08 (0.49-2.39) |       |       |
| EDU4 x INC3                   | 3.00* (1.27-7.12) | 0.87 (0.38-2.00) |       |       |
| EDU4 x INC4                   | 2.65* (1.04-6.78) | 0.66 (0.27-1.58) |       |       |
| Hosmer-Lemeshow test, p Value | 0.967             | 0.530            | 0.304 | 0.471 |

N, number; OR, odds ratio; CI, confidence interval; All models were adjusted for age, marital status, residential area, occupation, housing status, universal health insurance, private health insurance, survey year, smoking, alcohol consumption, routine physical exercise, daily sleep duration, daily energy intake, self-perceived stress, self-perceived health, hypertension, dyslipidemia, and diabetes; All estimates were obtained by considering a stratified cluster sampling design.

\* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

†Models 1 included only main effects terms for all variables.

‡Models 2 included both main effects terms and two-way interaction effects terms for all variables.

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4 158 Among women, according to Model 1, the OR was 0.59 (95% CI = 0.46–0.75) in  
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6 159 participants who had at least a college education compared with those who did not go beyond  
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8 160 elementary school, and the OR was 0.73 (95% CI = 0.60–0.89) among those with incomes in  
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10 161 highest quartile compared with those with incomes in the lowest quartile. In contrast,  
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12 162 according to Model 2, the OR was 0.13 (95% CI = 0.02–0.89) among participants with at  
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14 163 least a college education compared with participants who did not go beyond elementary  
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16 164 school. Income alone was not significant. In terms of an interaction effect, one combination  
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18 165 of educational and income levels was marginally significant relative to the reference  
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20 166 combination (p = 0.053).  
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### 26 168 **Predicted probability of being obese**

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28 169 The predicted probabilities for a participant to be obese were obtained from Model 1 and  
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30 170 from Model 2; these results are displayed graphically in Figure 1 for men and in Figure 2 for  
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32 171 women.  
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37 173 **Figure 1** Predicted probabilities of being obese (and their 95% confidence intervals)  
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39 174 by education for each income level in men in a model with only main effects (A) and a model  
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41 175 with both main and interaction effects (B): the Fifth Korea National Health and Nutrition  
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43 176 Examination Survey (KNHANES V), 2010–2012, South Korea  
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48 178 **Figure 2** Predicted probabilities of being obese (and their 95% confidence intervals)  
49  
50 179 by education for each income level in women in a model with only main effects (A) and a  
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52 180 model with both main and interaction effects (B): the Fifth Korea National Health and  
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54 181 Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea  
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183 The predicted probabilities of being obese differed for Models 1 and 2. The pattern of  
184 the changes in the predicted probability for each income level was uniform across educational  
185 levels according to Model 1 (the left panel in each figure), but it was very erratic according to  
186 Model 2 (the right panel in each figure). Additionally, there were clear sex differences in  
187 these patterns in Models 1 and 2.

188 Findings among men can be summarized as follows: 1) Although men in two income  
189 categories had the highest and the lowest predicted probabilities across all educational levels  
190 in Model 1, no income level had these distinctions with respect to all educational levels in  
191 Model 2. 2) The group with the highest predicted probability according to Model 1 and 2  
192 differed: it was junior high school graduates with incomes in the second lowest quartile in  
193 Model 1 (predicted probability = 0.392), but it was junior high school graduates with incomes  
194 in the lowest quartile in Model 2 (predicted probability = 0.414). 3) The group with the  
195 lowest predicted probability also differed between Models 1 and 2: it was participants who  
196 did not go beyond elementary and who had incomes in the lowest quartile in Model 1  
197 (predicted probability = 0.292), but it was those did not go beyond elementary school and  
198 who had incomes in second highest quartile in Model 2 (predicted probability = 0.243). 4)  
199 The gradient (or range) between the highest and lowest predicted probabilities was 0.099 in  
200 Model 1 but 0.172 in Model 2.

201 Likewise, findings among women can be summarized as follows. 1) Although  
202 women in two income levels had the highest and the lowest predicted probabilities across all  
203 educational levels in Model 1, no income level had these distinctions in Model 2. 2) The  
204 group with the highest predicted probability differed between Models 1 and 2: it was junior

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4 205 high school graduates with incomes in the lowest quartile in Model 1 (predicted probability =  
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6 206 0.370), but it was participants who did not go beyond elementary school and who had  
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8 207 incomes in the lowest quartile in Model 2 (predicted probability = 0.487). 3) The group with  
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10 208 the lowest predicted probability was the same in Models 1 and 2: it was those with at least a  
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12 209 college education with incomes in the highest quartile in Model 1 (predicted probability =  
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14 210 0.183) and Model 2 (predicted probability = 0.218). 4) The gradient in the predicted  
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16 211 probability was 0.187 in Model 1 and 0.269 in Model 2.  
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## 213 **DISCUSSION**

### 214 **Comparison to previous studies**

215 As shown in previous papers,<sup>1-3</sup> most studies of the relationship between socioeconomic  
216 status and obesity have focused on main rather than interaction effects. Those studies showed  
217 that socioeconomic status and obesity are negatively correlated in both men and women in  
218 developed countries. However, this study found that the associations of income with obesity  
219 were very erratic across education levels in models incorporating interaction-effect terms  
220 (Model 2) in comparison with models including only main-effect terms (Model 1), and sex  
221 differences in the associations were much clearer in Model 2 compared with Model 1. Among  
222 men, although only education was significant in Model 1, the main effect of income and the  
223 interaction effects between income and education were significant in Model 2. Among  
224 women, although both education and income were significant in Model 1, only income (but  
225 no interaction effect) was significant in Model 2. Moreover, in case of the predicted  
226 probabilities of being obese, they differed more across educational levels in Model 2 than in  
227 Model 1. Furthermore, participants with the highest predicted probability differed between

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4 228 Models 1 and 2. This suggests that the aforementioned well-known negative association  
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6 229 between socioeconomic status and obesity may not be valid in models incorporating  
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8 230 interaction-effect terms among various characteristics. This study obtained similar results  
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10 231 with regard to abdominal obesity as this study did here with regard to general obesity (these  
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12 232 results are available on request).  
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### 16 17 234 **Plausible mechanisms**

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19 235 Based on these results, this study sought to answer the following two questions. First, with  
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21 236 regard to its association with obesity, why does education sometimes interact with income  
22  
23 237 and why does the interaction differ by sex? This study believes that two different factors may  
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25 238 be involved in this issue. More education may discourage obesity insofar as it promotes a  
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27 239 more efficient use of health-related services and products<sup>13 14</sup> and an enhanced sense of  
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29 240 control and empowerment.<sup>15 16</sup> In addition, and less directly, more education may help people  
30  
31 241 earn a higher income, and a higher income may discourage obesity by increasing access to  
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33 242 higher quality food and better medical care.<sup>13 14</sup> However, in a subgroup of people (e.g., men  
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35 243 with certain sociocultural characteristics), a higher income may be positively associated with  
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37 244 obesity even though more education leads to higher income. Thus, more education and a  
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39 245 higher income may lead to a higher likelihood of being obese among this subgroup of people.  
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44 246 It is generally known that women with a high level of education tend to be more  
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46 247 worried about weight control than men with the same level of education.<sup>17</sup> This may be  
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48 248 because obese women they may be more penalized with regard to employment  
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50 249 opportunities,<sup>18</sup> wage equality,<sup>19</sup> and finding marriage partners than obese men.<sup>20</sup> On the  
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52 250 other hand, even men with a high income tend to feel more comfortable being overweight  
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54 251 than do women in the same income group.<sup>21</sup> This can be explained in part by the notion of

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4 252 habitus and Bourdieu's theory saying that the body has symbolic value in size and shape for  
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6 253 people but valuations of the body differ by sex.<sup>22 23</sup>  
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9 254 Even in a developed society such as South Korea, men have more political and  
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11 255 economic influence and are the primary wage earners for families, and most jobs tend to be  
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13 256 awarded first to men. Sex differences in body image are also pronounced in South Korea:  
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15 257 according to an international study of body image and weight control in young, educated  
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17 258 adults, the age-adjusted prevalence of feeling overweight was the second lowest in Korean  
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19 259 men (14%) compared with in men in the other 22 countries, but the prevalence of seeing  
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21 260 oneself as overweight was the highest in Korean women (77%).<sup>21</sup> Thus, local culture and  
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23 261 norms put greater pressure on women than on men to lose weight, as indicated in previous  
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25 262 studies.<sup>21 24 25</sup>  
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29 263 As a second question to be raised from the results of this study, after including the  
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31 264 interaction-effect terms in this study, why did the predicted probabilities of being obese  
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33 265 follow erratic rather than uniform patterns for both education and income levels, and why  
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35 266 were there sex differences in this regard? One reason for the erratic patterns in the predicted  
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37 267 probabilities might be that education or income may interact with some other covariate(s).  
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39 268 For example, the association between obesity and income may be influenced by stress level  
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41 269 in men<sup>26</sup> and health behaviors caused by a high level of stress, such as smoking cigarettes and  
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43 270 drinking alcohol, thereby contributing to the positive association between socioeconomic  
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45 271 status and obesity in men.<sup>27 28</sup> Another reason may be that, although education or income  
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47 272 interacts with a covariate, different combinations between levels of education or income and  
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49 273 categories of the covariate may be differently associated with being obese.  
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53 274 As for the sex differences in the predicted probabilities of being obese for both  
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55 275 education and income levels, there are three potential reasons. First, these sex differences  
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4 276 partly derive from sex differences in the covariates that interact with education or income.  
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6 277 For example, in the present study, men's educational level showed significant interaction  
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8 278 effects with residential area, excessive alcohol consumption, self-perceived stress, self-  
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10 279 perceived health, and survey year, whereas women's educational level interacted significantly  
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12 280 with age, marital status, housing status, having hypertension, and being diabetic (results are  
13  
14 281 not shown). Second, although a covariate interacts with education or income in both men and  
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16 282 women, the magnitude of the interactions between the categories of the covariate and levels  
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18 283 of education or income might differ by sex. Previous studies showed that, unlike the case in  
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20 284 women, an increase in income does not result in an equivalent adaptation to a healthier  
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22 285 behavior in men.<sup>29</sup> Finally, there may be sex differences in the reverse causation between  
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24 286 education or income and obesity. For example, in certain patriarchal societies, girls with a  
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26 287 health problem may be less likely to have a high level of education than their male  
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28 288 counterparts.<sup>30</sup>  
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### 35 290 **Public health implications**

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37 291 From a policy perspective, it is of interest whether as a government attempts to provide  
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39 292 people with the highest level of education, its actions can lead to a reduction in the  
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41 293 prevalence of obesity and the socioeconomic gradient in such prevalence. Though caution is  
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43 294 required when making policy predictions based on findings from cross-sectional data,  
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45 295 according to the findings of this study, the answer might be "no." An enhanced governmental  
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47 296 educational policy that enables all men to complete the highest level of formal education  
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49 297 would reduce the gradient in the predicted probability of being obese by 53%, from 0.130 to  
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51 298 0.061, but it would raise the average predicted probability by 26%, from 0.287 to 0.362.  
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53 299 Conversely, in women, the same enhanced educational policy would raise the gradient in the  
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4 300 predicted probability by 77%, from 0.071 to 0.126, but it would lower the average predicted  
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6 301 probability by 36%, from 0.440 to 0.283. This suggests that, to meet both goals (low  
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8 302 prevalence of obesity and reduced gradient by socioeconomic status), educational policies  
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10 303 should be implemented in combination with other social policies, and these governmental  
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12 304 efforts should be differentiated by sex. These results may elicit a new debate about whether  
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14 305 educational policies should consider health consequences.<sup>31 32</sup>  
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### 20 307 **Strengths and limitations**

21 308 This study analyzed data from sample of nationally representative South Korean adults,  
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23 309 providing abundant information about anthropometric measures, socio-demographic  
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25 310 characteristics, lifestyle behaviors, and medical conditions. This study shows by means of a  
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27 311 quantified prediction what would happen if policies to reduce obesity prevalence did not  
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29 312 consider complex interactions among characteristics of individuals. Above all, this study is  
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31 313 the first to address the association of socioeconomic status with obesity while fully  
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33 314 considering both main effects and interaction effects.  
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37 315 This study has several limitations. The cross-sectional study design precludes causal  
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39 316 inferences about the relationship between socioeconomic status and obesity. Moreover, the  
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41 317 data were collected a self-report survey, which may have resulted in measurement error and  
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43 318 recall bias. Other potential covariates, such as genetics, social network, and parental obesity,  
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45 319 were not included in analyses because such information was not available. Unobserved  
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47 320 factors, such discount rate and risk aversion, may have influenced both socioeconomic status  
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49 321 and body weight.<sup>33 34</sup>  
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4 323 **CONCLUSIONS**

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6 324 This is the first study to investigate the association of socioeconomic status with obesity  
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8 325 while fully considering both main effects and interaction effects. This study highlights the  
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10 326 importance of interaction effects in studies of associations of socioeconomic status with  
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12 327 obesity. According to the results, moving from models evaluating only main effects to  
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14 328 models evaluating both main and interaction effects may change the association of  
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16 329 socioeconomic status with obesity, the group with the highest likelihood of obesity, the  
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18 330 gradient in the likelihood of obesity by socioeconomic status, and sex differences in the  
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20 331 associations of socioeconomic status with obesity. These results suggest that studies of the  
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22 332 association between socioeconomic status and obesity should include interaction-effect terms  
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24 333 for all characteristics and consider sex differences, and that policy efforts to reduce obesity  
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26 334 and the resulting socioeconomic gradients should be established from the results of those in-  
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28 335 depth studies. Moreover, further research is needed to examine whether these findings are  
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30 336 valid in other sociocultural settings.  
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## Contributors

WC conceived and designed the study, conducting the literature review and the statistical analysis, writing the paper. JK collected and managed the data. JK, SJL and SL participated in reviewing the literature and writing the paper.

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## Competing interests

None declared.

## Ethics approval

Institutional Review Board of Yonsei University Graduate School of Public Health.

## Provenance and peer review

Not commissioned; externally peer reviewed.

## Data sharing statement

The data used in this study are available from the Korean Centers for Disease Control and

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Prevention database.

For peer review only

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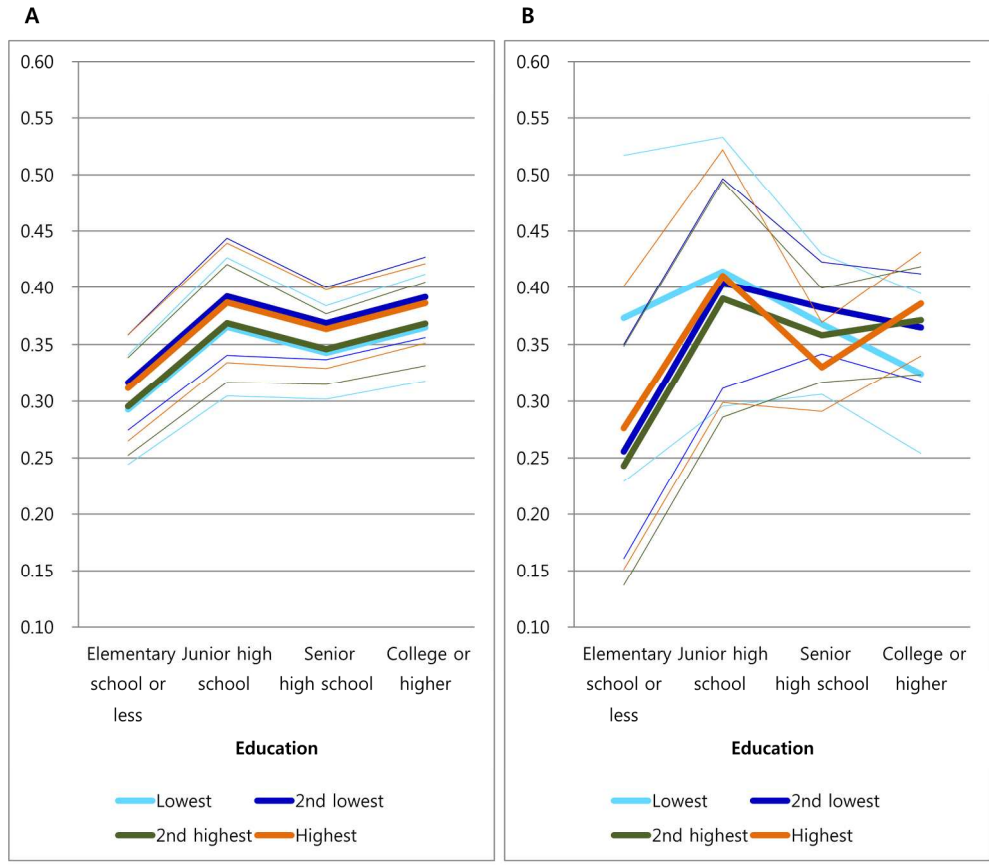


Figure 1 Predicted probabilities of being obese (and their 95% confidence intervals) by education for each income level in men in a model with only main effects (A) and a model with both main and interaction effects (B): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea

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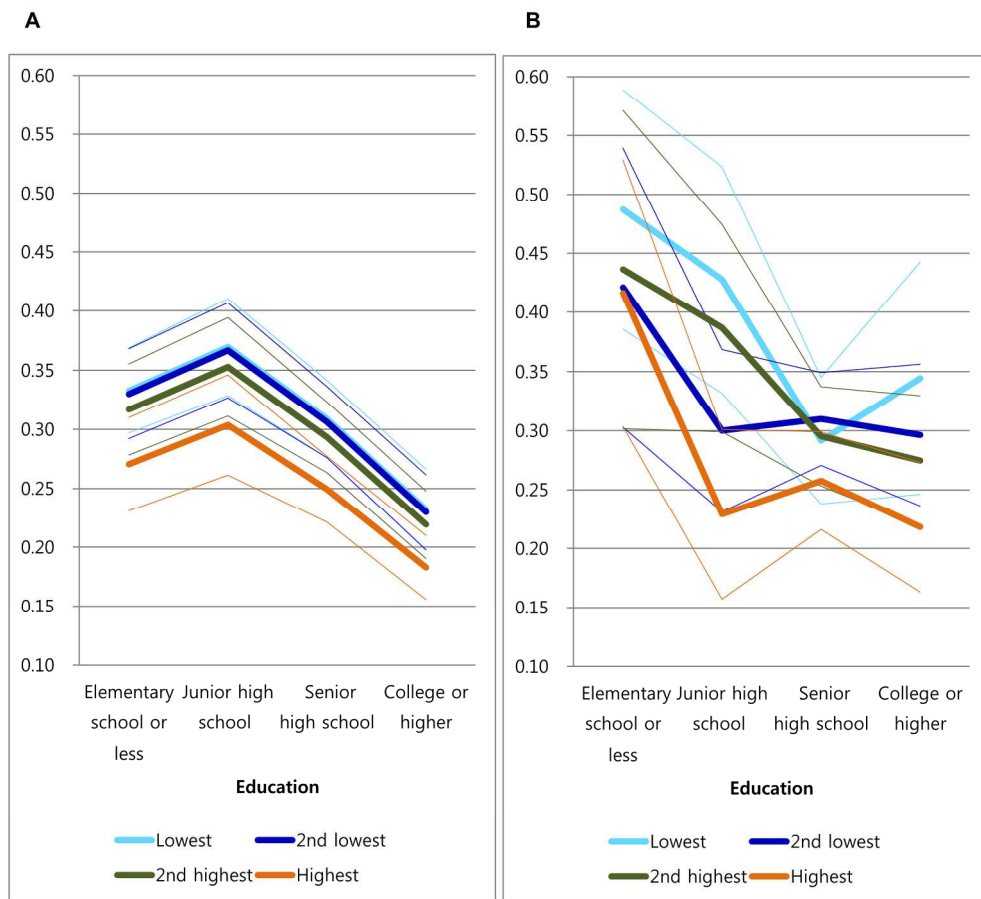


Figure 2 Predicted probabilities of being obese (and their 95% confidence intervals) by education for each income level in women in a model with only main effects (A) and a model with both main and interaction effects (B): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea

196x179mm (300 x 300 DPI)

## STROBE Statement—checklist of items that should be included in reports of observational studies

|                              | Item No | Recommendation   |
|------------------------------|---------|--|
| <b>Title and abstract</b>    | 1       | (a) Indicate the study's design with a commonly used term in the title or the abstract<br>→ We indicated it in the design part of the abstract (page 2).<br>(b) Provide in the abstract an informative and balanced summary of what was done and what was found<br>→ We provided it in the abstract (pages 2-3).   |
| <b>Introduction</b>          |         |  |
| Background/rationale         | 2       | Explain the scientific background and rationale for the investigation being reported<br>→ We explained them in the introduction (pages 5-6).   |
| Objectives                   | 3       | State specific objectives, including any prespecified hypotheses<br>→ We stated them in the introduction (pages 5-6)   |
| <b>Methods</b>               |         |  |
| Study design                 | 4       | Present key elements of study design early in the paper<br>→ We presented them in the measures and variables section of the materials and methods (pages 7-8).   |
| Setting                      | 5       | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection<br>→ We described them in the data source and study sample sections of the materials and methods (pages 6-7).  |
| Participants                 | 6       | (a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up<br><i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls<br><b><i>Cross-sectional study</i></b> —Give the eligibility criteria, and the sources and methods of selection of participants<br>→ We presented them in the data source and study sample sections of the materials and methods (pages 6-7).<br>(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed<br><i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case<br>→ N/A |
| Variables                    | 7       | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable<br>→ We clearly defined them in the measures and variables section of the materials and methods (pages 7-8).  |
| Data sources/<br>measurement | 8*      | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group.<br>→ We indicated them in the materials and methods (pages 6-8).   |
| Bias                         | 9       | Describe any efforts to address potential sources of bias  |

|                        |     |   |
|------------------------|-----|---|
|                        |     | → We described them in the strengths and limitations section of the discussion (page 24).   |
| Study size             | 10  | Explain how the study size was arrived at<br>→ We explained the study size in the data source and study sample section of the materials and methods (pages 6-7).  |
| Quantitative variables | 11  | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why<br>→ We explained quantitative variables' handling in the measures and variables section of the materials and methods (pages 7-8).   |
| Statistical methods    | 12  | (a) Describe all statistical methods, including those used to control for confounding<br>→ We described statistical methods in the analytic procedures section of the materials and methods (pages 8-10).<br>(b) Describe any methods used to examine subgroups and interactions<br>→ We described statistical methods in the analytic procedures section of the materials and methods (pages 8-10).<br>(c) Explain how missing data were addressed<br>→ N/A<br>(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed<br><i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed<br><b><i>Cross-sectional study</i></b> —If applicable, describe analytical methods taking account of sampling strategy<br>→ We described them in the analytic procedures section of the materials and methods (pages 8-10).<br>(e) Describe any sensitivity analyses<br>→ N/A |
| <b>Results</b>         |     |   |
| Participants           | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed<br>→ We reported them in the data source and study sample section of the materials and methods and in the table (pages 6-7, 11-13).<br>(b) Give reasons for non-participation at each stage<br>→ N/A<br>(c) Consider use of a flow diagram<br>→ N/A   |
| Descriptive data       | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders<br>→ We described them in the data source and study sample section of the materials and methods and in the table (pages 6-7, 11-13).<br>(b) Indicate number of participants with missing data for each variable of interest<br>→ N/A<br>(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)<br>→ N/A  |
| Outcome data           | 15* | <i>Cohort study</i> —Report numbers of outcome events or summary measures over time<br><i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure   |

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|                          |    | <b><u>Cross-sectional study</u></b> —Report numbers of outcome events or summary measures<br>→ We reported them in the table (pages 11-13; Table 1).   |
| Main results             | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included<br>→ We indicated them in the results and the table (pages 15-18, Table 2)  |
|                          |    | (b) Report category boundaries when continuous variables were categorized<br>→ We reported them in the measures and variables section of the materials and methods (pages 7-8).  |
|                          |    | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period<br>→ N/A  |
| Other analyses           | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses<br>→ N/A  |
| <b>Discussion</b>        |    |  |
| Key results              | 18 | Summarise key results with reference to study objectives<br>→ We indicated them in the comparison to previous studies section of the discussion (pages 20-21).   |
| Limitations              | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias<br>→ We discussed them in the strengths and limitations section of the discussion (page 24).                                  |
| Interpretation           | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence<br>→ We discussed them in the discussion (pages 20-24).   |
| Generalisability         | 21 | Discuss the generalisability (external validity) of the study results<br>→ We discussed it in the public health implications section of the discussion and in the conclusion (pages 23-25).  |
| <b>Other information</b> |    |  |
| Funding                  | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based<br>→ This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. |

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Gender-specific interactions between education and income in relation to obesity: a cross-sectional analysis of the Fifth Korean National Health and Nutrition Examination Survey (KNHANES V)

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| Secondary Subject Heading:      | Sociology   |
| Keywords:                       | Obesity, Education, Income, Gender, South Korea   |
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14 Woojin Chung,<sup>1,2</sup> Seung-ji Lim,<sup>3</sup> Sunmi Lee,<sup>3</sup> Rooul Kim,<sup>4</sup> Jaeyeun Kim,<sup>3,5\*</sup>  
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## 1 ABSTRACT

### 3 Objectives

4 To examine whether the well-known negative association between socioeconomic status and  
5 obesity in developed countries remains valid upon including when the interaction-effect  
6 terms of all studied variables.

### 7 Design

8 A cross-sectional study. Education and income levels were chosen as socioeconomic status  
9 indicators. Socio-demographics, lifestyles and medical conditions were used as covariates in  
10 multivariate logistic regression models. Adjusted odds ratios and predicted probabilities of  
11 obesity were computed and adjusted for a complex survey design.

### 12 Setting

13 Data were obtained from the Fifth Korea National Health and Nutrition Examination Survey  
14 (2010-2012).

### 15 Participants

16 The sample included 7,337 male and 9,908 female participants aged 19 years or older.

### 17 Outcome measure

18 Obesity was defined as body mass index of 25 or more, according to a guideline for Asians.

### 19 Results

20 In models with no interaction-effect terms, only education was a significantly associated with  
21 obesity in men, but both income and education were significant in women. However, in  
22 models with the interaction-effect terms, income was significant in men but education was  
23 significant in women. The interaction effect between income and education was significant in

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4 24 men but not in women. Participants having the highest predicted probability of obesity over  
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6 25 educational and income levels differed between the two models, and between men and  
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8 26 women. Though caution is necessary when interpreting the findings, the predicted  
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10 27 probabilities of obesity suggest that a policy providing all men with the highest level of  
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12 28 formal education would counter-intuitively increase their rate of obesity by as much as 26%.

### 29 **Conclusions**

30 The well-known association between socioeconomic status and obesity may not be valid  
31 when interaction effects are included. Ignoring these effects and their gender differences may  
32 result in the targeting of wrong populations for reducing obesity prevalence and its resultant  
33 socioeconomic gradients. Further research is needed to examine whether these findings are  
34 valid in other sociocultural settings.

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4 36 **Article summary**

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7 37 **Strengths and limitations of this study**

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9 38 1. This is the first study to investigate the association of socioeconomic status with  
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11 39 obesity while considering both main effects and interaction effects.  
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13 40 2. This study analyzed data from a nationally representative sample of South Korean  
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15 41 adults, providing abundant information about anthropometric measures, socio-  
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17 42 demographic characteristics, lifestyle behaviors, and medical conditions.  
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19 43 3. This study shows by means of a quantified prediction what would happen if policies  
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21 44 to reduce obesity prevalence did not consider complex interactions among  
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23 45 characteristics of individuals.  
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25 46 4. The cross-sectional study design used in this study precludes causal inferences about  
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27 47 the relationship between socioeconomic status and obesity.  
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## 1 INTRODUCTION

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3 Numerous studies have investigated various factors related to obesity, and have identified  
4 associations between socioeconomic status and obesity, which are negatively correlated in  
5 both men and women in developed countries, although this is more consistent in women than  
6 in men.<sup>1-3</sup> However, because most empirical studies of obesity have ignored the interaction  
7 effects among various characteristics, these studies have failed to detect complex associations  
8 between different levels of socioeconomic status in relation to obesity; moreover, they have  
9 failed to explain differences among different population groups regarding the mechanisms  
10 through which socioeconomic status becomes associated with obesity.

11 For example, when the interaction effects among various characteristics are  
12 considered, previous studies have not answered the question as to whether the above-  
13 mentioned, well-known associations between socioeconomic status and obesity remain valid.  
14 Moreover, they have seldom explored why a socioeconomic status indicator sometimes  
15 interacts with another socioeconomic status indicator with regard to obesity, and whether the  
16 interaction differs by gender; whether the likelihood of being obese with regard to some  
17 levels of socioeconomic status remains the same before and after consideration of the  
18 interaction effects; and whether government can reduce the prevalence of obesity and change  
19 the socioeconomic gradient in the prevalence of this condition by providing all individuals  
20 with the highest level of socioeconomic status possible.

21 Attempting to fill the gap between previous findings and the unanswered questions,  
22 this study chose education and income levels as socioeconomic status indicators because they  
23 complement each other: educational level is established in early adulthood and tends to  
24 remain unchanged later in life, while income level may change throughout adult life. In

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4 25 particular, this study used data from South Korea, which has industrialized rapidly and is now  
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6 26 categorized as one of the ten largest advanced economies in the world.<sup>4</sup> Nevertheless, South  
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8 27 Korea is still noted for pronounced gender inequality almost everywhere, especially in the  
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10 28 labor markets.<sup>5 6</sup>

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13 29 This study considered two models for each gender: one that included only the main-  
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15 30 effect term of each variable, and the other included the two-way interaction-effect terms  
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17 31 between variables, as well as the main-effect term of each variable. Considering the complex  
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19 32 survey design, this study used multivariate logistic regression analyses to compute the odds  
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21 33 ratios of obesity and to predict the probability that a man or woman would be obese if he or  
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23 34 she had a particular set of education and income levels.  
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## 28 36 **MATERIALS AND METHODS**

### 29 37 **Data source and study sample**

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32 38 This study was based on the Fifth Korea National Health and Nutrition Examination Survey  
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34 39 (KNHANES V), 2010–2012, which used a stratified multistage clustered probability  
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36 40 sampling design to collect data on the non-institutionalized, civilian population of South  
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38 41 Korea on behalf of the Korean Centers for Disease Control and Prevention.<sup>7</sup> This survey was  
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40 42 composed of a health interview and a nutrition survey conducted at the participants' homes,  
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42 43 as well a physical examination conducted by physicians at designated examination centers.  
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44 44 Detailed information about the survey design and characteristics is available at the  
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46 45 KNHANES website.<sup>7</sup>

47 46 From KNHANES V, this study accessed data from a pool of 25,534 individuals  
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49 47 (8,958 in 2010, 8,518 in 2011, and 8,058 in 2012). Of this group, 24,173 had participated in  
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4 48 the interviews, and 18,571 individuals aged 19 years or older underwent physical  
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6 49 examinations. A total of 17,245 (92.86%) participants (7,337 men, 9,908 women) were  
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8 50 included in this study because they had the required information in their files. The ethical  
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10 51 review board of the educational institution where the research was conducted approved this  
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12 52 study.  
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### 18 54 **Measures and variables**

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20 55 The obesity status of each participant was determined anthropometrically using data from the  
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22 56 physical examination. Height was measured using a portable stadiometer, and body weight  
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24 57 was measured using a calibrated balance-beam scale, and the body mass index (BMI) was  
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26 58 calculated from these height and weight measurements. According to the guidelines proposed  
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28 59 by the World Health Organization indicating that Asians have a lower average BMI,<sup>8</sup> this  
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30 60 study defined general obesity as a BMI of at least 25. Also, because the percentage of  
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32 61 participants with BMI of less than 18.5 in the sample was very small (4.5%, 781 participants),  
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34 62 we combined participants with BMI of less than 18.5 and those with BMI between 18.5 to 25  
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36 63 into a single group. Therefore, a dichotomous outcome variable was constructed with a value  
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38 64 of 1 (obesity, BMI of 25 or higher) and 0 (non-obesity, BMI of less than 25).<sup>9-11</sup>  
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42 65 Levels of education and income were chosen as socioeconomic status indicators.  
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44 66 Education was defined as the highest level of formal education completed as of the date of  
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46 67 the interview. This study categorized education into four levels: elementary school or less,  
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48 68 junior high school, senior high school, and college or more. For income, this study used an  
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50 69 equivalized monthly household income calculation ( $[\text{monthly overall household income}]$   
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52 70  $[\text{household size}]^{-0.5}$ ) and divided the participants into four quartiles.  
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4 71 Nine sociodemographic characteristics, including gender, were incorporated as  
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6 72 covariates. Age was treated as a continuous variable, and marital status was categorized into  
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8 73 married, formerly married, and never married. Residential area was divided into metropolitan  
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10 74 urban area, non-metropolitan urban area, and rural area. Occupation was grouped into  
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12 75 unemployed, office worker, and manual worker. Housing status was coded in terms of  
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14 76 whether a participant was a renter or a home owner. Participants were categorized according  
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16 77 to whether they were enrolled in National Health Insurance or Medical Care Aid for regular  
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18 78 or low-income individuals, respectively, with regard to the universal health insurance  
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20 79 program. Participants with private health insurance were also noted. Survey year was added  
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22 80 to control for any fixed time effect.

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26 81 This study also incorporated ten characteristics about lifestyle and medical conditions.  
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28 82 Participants were grouped in terms of the following categories: 1) smoking, 2) excessive  
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30 83 alcohol consumption (at high risk due to drinking according to the gender-specific guidelines  
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32 84 of the World Health Organization),<sup>12</sup> 3) routinely exercising (physical activity as defined as  
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34 85 the participation in moderate or vigorous exercise for a respective frequency and duration),<sup>13</sup>  
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36 86 4) daily sleep duration (sleeping less than 7 h per day was defined as sleeping for a short  
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38 87 duration),<sup>14</sup> 5) daily energy intake (moderate energy intake was defined as total energy intake  
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40 88 within 1.25× of participants' estimated daily energy requirement),<sup>15</sup> 6) self-perceived stress, 7)  
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42 89 self-perceived health, 8) hypertension, 9) dyslipidemia, and 10) diabetes. The presence of the  
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44 90 last three chronic diseases was determined by a prior physician diagnosis at the pre-surgery  
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### 50 51 52 53 93 **Analytic procedures**

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55 94 A six-fold analysis was performed. First, this study tested differences in the distributions of

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4 95 variables among men and women using the *t*-test for continuous variables and the  $\chi^2$  test for  
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6 96 categorical variables. Second, this study tested the association of each variable with obesity  
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8 97 by gender using the  $\chi^2$  test. Third, gender interaction effects were examined, for which simple  
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10 98 logistic regression models were constructed with main effects for gender and the variable of  
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12 99 interest as well as the interaction effects of the two variables. Due to the results, the  
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14 100 remaining analyses were stratified by gender.

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17 101 Fourth, to fit the multivariate logistic regression models, this study continued to re-  
18  
19 102 categorize each of the variables and defined each variable's reference category differently  
20  
21 103 until no strong multicollinearity was found for the main-effect models and no evidence of a  
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23 104 lack of goodness-of-fit was found in each model. The values for the variance inflation factor  
24  
25 105 were less than 3.65, and p-values based on the Hosmer-Lemeshow statistic were higher than  
26  
27 106 0.26.

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29  
30 107 Fifth, this study estimated the adjusted odds ratios (ORs) of obesity and their 95%  
31  
32 108 confidence intervals (CIs) after fully adjusting for covariates. Two models were considered  
33  
34 109 for each gender: Model 1 included only the main-effect term of every variable, and Model 2  
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36 110 included the main-effect terms for each variable as well the two-way interaction-effect terms  
37  
38 111 between the variables.

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40  
41 112 Finally, to assess the association of each level of a socioeconomic status indicator  
42  
43 113 with obesity and to compare these associations across categories for both socioeconomic  
44  
45 114 status indicators, this study predicted the probability of a participant being obese (and its 95%  
46  
47 115 confidence intervals) if he or she had a particular set of education and income levels. These  
48  
49 116 probabilities, which were calculated by gender, denote the average of all participants'  
50  
51 117 probabilities if each participant belonged to a particular set of education and income levels,  
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53 118 while maintaining participant characteristics for the other variables constant.  
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4 119 All analyses and tests were conducted considering the sampling design of the survey.  
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6 120 However, for convenience, the descriptive statistics are shown as unweighted. P-values <  
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8 121 0.05 were considered statistically significance. The SAS 9.2 software (SAS Institute, Cary,  
9  
10 122 NC, USA) and STATA 12 software (StataCorp, College Station, TX, USA) were used to  
11  
12 123 perform all statistical analyses.  
13  
14  
15 124

## 125 **RESULTS**

### 126 **Descriptive statistics**

127 The rate of obesity was significantly higher in men (34.96%) than in women (29.67%), as  
128 indicated by the significantly higher BMI in men than in women (Table 1). All characteristics  
129 differed significantly by gender except for residential area, housing status, enrollment in a  
130 private health insurance plan, survey year, daily sleep duration, and diabetes status.  
131

132 **Table 1** Sample characteristics and their associations with obesity by gender: the Fifth Korea National Health and Nutrition Examination  
 133 Survey (KNHANES V), 2010-2012, South Korea

|                                       | Distribution, N (%) |              |          | Obesity, % |         |          |
|---------------------------------------|---------------------|--------------|----------|------------|---------|----------|
|                                       | Men                 | Women        | p Value† | Men        | Women   | p Value¶ |
| Body mass index, kg m <sup>-2</sup> * | 23.97 (3.1)         | 23.43 (3.6)  | <0.001   |            |         |          |
| Obesity                               | 2565 (35.0)         | 2940 (29.7)  | <0.001   |            |         |          |
| Age, years*                           | 50.79 (16.4)        | 50.48 (16.6) | <0.001   | 35.1‡      | 34.7‡   | <0.001   |
| Marital status                        |                     |              | <0.001   | <0.001§    | <0.001§ | <0.001   |
| Married                               | 5848 (79.7)         | 6887 (69.5)  |          | 36.0       | 30.5    |          |
| Formerly married                      | 339 (4.6)           | 1803 (18.2)  |          | 30.1       | 37.4    |          |
| Never-married                         | 1150 (15.7)         | 1218 (12.3)  |          | 31.0       | 13.4    |          |
| Residential area                      |                     |              | 0.446    | 0.259§     | <0.001§ | <0.001   |
| Metro urban                           | 3240 (44.2)         | 4404 (44.5)  |          | 35.2       | 27.0    |          |
| Non-metro urban                       | 2523 (34.4)         | 3471 (35.0)  |          | 36.6       | 29.2    |          |
| Rural                                 | 1574 (21.4)         | 2033 (20.5)  |          | 31.9       | 36.4    |          |
| Education                             |                     |              | <0.001   | <0.001§    | <0.001§ | <0.001   |
| Elementary school or less             | 1294 (17.6)         | 3168 (32.0)  |          | 26.6       | 40.2    |          |
| Junior high school                    | 867 (11.8)          | 1024 (10.3)  |          | 36.1       | 38.6    |          |
| Senior high school                    | 2617 (35.7)         | 3136 (31.7)  |          | 34.5       | 27.1    |          |
| College or more                       | 2559 (34.9)         | 2580 (26.0)  |          | 39.3       | 16.4    |          |
| Income, quartiles                     |                     |              | <0.001   | 0.002§     | <0.001§ | <0.001   |
| Lowest                                | 1694 (23.1)         | 2641 (26.6)  |          | 28.4       | 36.8    |          |
| 2nd lowest                            | 1924 (26.2)         | 2514 (25.4)  |          | 36.5       | 31.7    |          |
| 3rd lowest                            | 1739 (23.7)         | 2177 (22.0)  |          | 34.9       | 28.0    |          |

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|----|----------------------------|-------------|-------------|--------|---------|---------|--------|
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| 3  |                            |             |             |        |         |         |        |
| 4  |                            |             |             |        |         |         |        |
| 5  | Highest                    | 1980 (27.0) | 2576 (26.0) |        | 39.1    | 21.8    |        |
| 6  | Occupation                 |             |             | <0.001 | <0.001§ | <0.001§ | <0.001 |
| 7  |                            |             |             |        |         |         |        |
| 8  | Unemployed                 | 1878 (25.6) | 5208 (52.6) |        | 28.7    | 31.1    |        |
| 9  | Office worker              | 1965 (26.8) | 1586 (16.0) |        | 42.1    | 17.5    |        |
| 10 | Manual worker              | 3494 (47.6) | 3114 (31.4) |        | 34.3    | 33.6    |        |
| 11 | Housing status             |             |             | 0.158  | 0.945§  | 0.843§  | 0.838  |
| 12 |                            |             |             |        |         |         |        |
| 13 | Renter                     | 5606 (76.4) | 7280 (73.5) |        | 35.1    | 29.5    |        |
| 14 | Home owner                 | 1731 (23.6) | 2628 (26.5) |        | 34.6    | 30.1    |        |
| 15 | Universal health insurance |             |             | <0.001 | 0.020§  | 0.004§  | <0.001 |
| 16 |                            |             |             |        |         |         |        |
| 17 | National Health Insurance  | 7204 (98.2) | 9609 (97.0) |        | 35.2    | 29.4    |        |
| 18 | Medical Care Aid           | 133 (1.8)   | 299 (3.0)   |        | 24.8    | 39.8    |        |
| 19 | Private health insurance   |             |             | 0.181  | <0.001§ | <0.001§ | <0.001 |
| 20 |                            |             |             |        |         |         |        |
| 21 | Non-holder                 | 2258 (30.8) | 2898 (29.3) |        | 29.3    | 34.9    |        |
| 22 | Holder                     | 5079 (69.2) | 7010 (70.7) |        | 37.5    | 27.5    |        |
| 23 | Survey year                |             |             | 0.831  | 0.695§  | 0.133§  | 0.162  |
| 24 |                            |             |             |        |         |         |        |
| 25 | 2010                       | 2592 (35.3) | 3364 (34.0) |        | 35.2    | 28.3    |        |
| 26 | 2011                       | 2494 (34.0) | 3380 (34.1) |        | 34.6    | 30.4    |        |
| 27 | 2012                       | 2251 (30.7) | 3164 (31.9) |        | 35.1    | 30.4    |        |
| 28 | Current smoking status     |             |             | <0.001 | 0.375§  | 0.936§  | 0.729  |
| 29 |                            |             |             |        |         |         |        |
| 30 | Non-smoker                 | 4336 (59.1) | 9359 (94.5) |        | 36.1    | 29.8    |        |
| 31 | Smoker                     | 3001 (40.9) | 549 (5.5)   |        | 33.3    | 27.1    |        |
| 32 | Alcohol consumption        |             |             | <0.001 | <0.001§ | 0.064§  | <0.001 |
| 33 |                            |             |             |        |         |         |        |
| 34 | Not excessive              | 4950 (67.5) | 8689 (87.7) |        | 31.5    | 30.1    |        |
| 35 | Excessive                  | 2387 (32.5) | 1219 (12.3) |        | 42.1    | 26.7    |        |
| 36 | Routine physical exercise  |             |             | <0.001 | 0.838§  | <0.001§ | 0.012  |
| 37 |                            |             |             |        |         |         |        |
| 38 |                            |             |             |        |         |         |        |
| 39 |                            |             |             |        |         |         |        |
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| 43 |                            |             |             |        |         |         |        |
| 44 |                            |             |             |        |         |         |        |
| 45 |                            |             |             |        |         |         |        |
| 46 |                            |             |             |        |         |         |        |
| 47 |                            |             |             |        |         |         |        |
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| 4  |                        |             |             |        |         |         |        |
| 5  | Physically active      | 1552 (21.2) | 1620 (16.4) |        | 35.6    | 32.8    |        |
| 6  | Physically inactive    | 5785 (78.8) | 8288 (83.6) |        | 34.8    | 29.1    |        |
| 7  |                        |             |             |        |         |         |        |
| 8  | Daily sleep duration   |             |             | 0.992  | 0.150§  | <0.001§ | 0.007  |
| 9  | Non-short              | 4291 (58.5) | 5717 (57.7) |        | 34.2    | 27.4    |        |
| 10 | Short                  | 3046 (41.5) | 4191 (42.3) |        | 36.0    | 32.8    |        |
| 11 |                        |             |             |        |         |         |        |
| 12 | Daily energy intake    |             |             | <0.001 | 0.818§  | <0.001§ | <0.001 |
| 13 | Not moderate           | 5859 (79.9) | 8306 (83.8) |        | 34.9    | 28.0    |        |
| 14 | Moderate               | 1478 (20.1) | 1602 (16.2) |        | 35.4    | 38.5    |        |
| 15 |                        |             |             |        |         |         |        |
| 16 | Self-perceived stress  |             |             | <0.001 | 0.969§  | 0.031§  | 0.236  |
| 17 | Not very high          | 7087 (96.6) | 9421 (95.1) |        | 35.1    | 29.5    |        |
| 18 | Very high              | 250 (3.4)   | 487 (4.9)   |        | 32.4    | 33.3    |        |
| 19 |                        |             |             |        |         |         |        |
| 20 | Self-perceived health  |             |             | <0.001 | 0.362§  | <0.001§ | 0.002  |
| 21 | Not very bad           | 7159 (97.6) | 9467 (95.5) |        | 35.2    | 29.1    |        |
| 22 | Very bad               | 178 (2.4)   | 441 (4.5)   |        | 24.2    | 42.4    |        |
| 23 |                        |             |             |        |         |         |        |
| 24 | Hypertension           |             |             | <0.001 | <0.001§ | <0.001§ | <0.001 |
| 25 | No                     | 5764 (78.6) | 7713 (77.8) |        | 32.6    | 24.3    |        |
| 26 | Yes                    | 1573 (21.4) | 2195 (22.2) |        | 43.6    | 48.5    |        |
| 27 |                        |             |             |        |         |         |        |
| 28 | Dyslipidemia           |             |             | <0.001 | <0.001§ | <0.001§ | 0.137  |
| 29 | No                     | 6859 (93.5) | 9065 (91.5) |        | 33.9    | 27.8    |        |
| 30 | Yes                    | 478 (6.5)   | 843 (8.5)   |        | 50.6    | 49.8    |        |
| 31 |                        |             |             |        |         |         |        |
| 32 | Diabetes               |             |             | 0.099  | 0.858§  | <0.001§ | <0.001 |
| 33 | No                     | 6661 (90.8) | 9219 (93.0) |        | 34.8    | 28.1    |        |
| 34 | Yes                    | 676 (9.2)   | 689 (7.0)   |        | 36.1    | 50.4    |        |
| 35 |                        |             |             |        |         |         |        |
| 36 | Number of participants | 7337        | 9908        |        | 7337    | 9908    |        |

N, number; All P-values were estimated by considering a stratified cluster sampling design.

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\*Mean (standard deviation).  
†P-value was estimated by using the t-test for continuous variables and  $\chi^2$  tests for categorical variables.  
‡For the continuous age variable, the proportion of obesity was obtained from people aged 50-59 years to which median age for each gender belonged.  
§P-value was estimated by  $\chi^2$  tests for each gender.  
¶P-value was estimated from the interaction effects terms between gender and each characteristic by using the logistic analysis.

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### 135 **Characteristics associated with obesity and gender differences**

136 Among men, the rate of obesity was significantly higher in participants who were married,  
137 had at least a college education, had an income in the highest quartile, had an office job, were  
138 National Health Insurance beneficiaries, had a private health insurance plan, consumed  
139 excessive alcohol, had hypertension, and had dyslipidemia (Table 1).

140 Among women, a significantly higher rate of obesity was observed in participants  
141 who were formerly married, lived in a rural area, did not go beyond elementary school, had  
142 incomes in the lowest quartile, were manual workers, were Medical Care Aid beneficiaries,  
143 had no private health insurance plan, were physically active, lacked adequate sleep, had  
144 moderate energy intake, reported very high levels of stress, had very poor self-perceived  
145 health, had hypertension, had dyslipidemia, and were diabetic. The rate of obesity differed  
146 significantly by gender with regard to all variables except for housing status, survey year,  
147 current smoking status, self-perceived stress, and had dyslipidemia.

### 149 **Adjusted associations of obesity with education and income**

150 Among men, according to the model with only main-effect terms (Model 1), the OR of  
151 obesity was 1.41 (95% CI = 1.12–1.77) in those with at least a college education compared  
152 with their counterparts who did not go beyond elementary school (Table 2). Conversely,  
153 according to the model with interaction-effect terms (Model 2), the OR was 0.05 (95% CI =  
154 0.01–0.32) among those with incomes in the highest quartile compared with those with  
155 incomes in the lowest quartile. Education alone was not significant. In terms of their  
156 association with obesity, education and income were found to interact with each other, as five  
157 combinations of educational and income levels were significant compared with their  
158 respective reference combinations.

159 **Table 2** Adjusted associations of education and income with obesity by gender: the Fifth Korea National Health and Nutrition Examination  
 160 Survey (KNHANES V), 2010-2012, South Korea

|                                  | Men (N=7337)       |                    | Women (N=9908)      |                    |
|----------------------------------|--------------------|--------------------|---------------------|--------------------|
|                                  | Model 1†           | Model 2‡           | Model 1†            | Model 2‡           |
|                                  | OR (95% CI)        | OR (95% CI)        | OR (95% CI)         | OR (95% CI)        |
| <b>Main effects</b>              |                    |                    |                     |                    |
| Education                        |                    |                    |                     |                    |
| Elementary school or less (EDU1) | 1.00               | 1.00               | 1.00                | 1.00               |
| Junior high school (EDU2)        | 1.41** (1.10-1.82) | 0.61 (0.06-6.56)   | 1.19 (0.98-1.44)    | 0.16* (0.03-0.89)  |
| Senior high school (EDU3)        | 1.27* (1.03-1.58)  | 0.57 (0.08-4.25)   | 0.89 (0.72-1.09)    | 0.13** (0.03-0.58) |
| College or more (EDU4)           | 1.41** (1.12-1.77) | 1.45 (0.16-13.04)  | 0.59*** (0.46-0.75) | 0.13* (0.02-0.89)  |
| Income, quartiles                |                    |                    |                     |                    |
| Lowest (INC1)                    | 1.00               | 1.00               | 1.00                | 1.00               |
| 2nd lowest (INC2)                | 1.13 (0.91-1.39)   | 0.11* (0.02-0.64)  | 0.99 (0.84-1.16)    | 1.13 (0.26-4.98)   |
| 3rd lowest (INC3)                | 1.01 (0.81-1.28)   | 0.18 (0.03-1.11)   | 0.93 (0.77-1.11)    | 1.16 (0.22-6.20)   |
| Highest (INC4)                   | 1.10 (0.87-1.39)   | 0.05** (0.01-0.32) | 0.73** (0.60-0.89)  | 1.58 (0.30-8.38)   |
| <b>Interaction effects</b>       |                    |                    |                     |                    |
| Education x Income               |                    |                    |                     |                    |
| EDU2 x INC2                      |                    | 1.91 (0.91-4.04)   |                     | 0.77 (0.44-1.33)   |
| EDU2 x INC3                      |                    | 1.88 (0.81-4.34)   |                     | 1.11 (0.60-2.06)   |

|                               |                   |                  |       |       |
|-------------------------------|-------------------|------------------|-------|-------|
| EDU2 x INC4                   | 1.72 (0.65-4.59)  | 0.51 (0.26-1.01) |       |       |
| EDU3 x INC2                   | 2.30* (1.17-4.52) | 1.58 (0.90-2.75) |       |       |
| EDU3 x INC3                   | 2.17* (1.05-4.47) | 1.34 (0.73-2.47) |       |       |
| EDU3 x INC4                   | 1.52 (0.67-3.44)  | 1.23 (0.67-2.24) |       |       |
| EDU4 x INC2                   | 2.74* (1.14-6.56) | 1.08 (0.49-2.39) |       |       |
| EDU4 x INC3                   | 3.00* (1.27-7.12) | 0.87 (0.38-2.00) |       |       |
| EDU4 x INC4                   | 2.65* (1.04-6.78) | 0.66 (0.27-1.58) |       |       |
| Hosmer-Lemeshow test, p Value | 0.967             | 0.530            | 0.304 | 0.471 |

N, number; OR, odds ratio; CI, confidence interval; All models were adjusted for age, marital status, residential area, occupation, housing status, universal health insurance, private health insurance, survey year, smoking, alcohol consumption, routine physical exercise, daily sleep duration, daily energy intake, self-perceived stress, self-perceived health, hypertension, dyslipidemia, and diabetes; All estimates were obtained by considering a stratified cluster sampling design.

\* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

†Models 1 included only main effects terms for all variables.

‡Models 2 included both main effects terms and two-way interaction effects terms for all variables.



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4 161 Among women, according to Model 1, the OR was 0.59 (95% CI = 0.46–0.75) in  
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6 162 participants who had at least a college education compared with those who did not go beyond  
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8 163 elementary school, and 0.73 (95% CI = 0.60–0.89) among those with incomes in the highest  
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10 164 quartile compared with those with incomes in the lowest quartile. In contrast, according to  
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12 165 Model 2, the OR was 0.13 (95% CI = 0.02–0.89) among participants with at least a college  
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14 166 education compared with participants who did not go beyond elementary school. Income  
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16 167 alone was not significant. In terms of an interaction effect, one combination of educational  
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18 168 and income levels was marginally significant relative to the reference combination  
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20 169 (p = 0.053).  
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### 26 171 **Predicted probability of being obese**

27  
28 172 The predicted probabilities for a participant to be obese if he or she had a particular set of  
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30 173 education and income levels were obtained from the model with only the main-effect term of  
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32 174 every studied variable (Model 1) and from the model with both the main-effect term of every  
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34 175 studied variable as well as the interaction-effect terms between all studied variables (Model  
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36 176 2); these results are displayed graphically in Figures 1 and 2 for men and women, respectively.  
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42 178 **Figure 1** Predicted probabilities of being obese (and their 95% confidence intervals)  
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44 179 by education for each income level in men in a model with only main effects (A) and a model  
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46 180 with both main and interaction effects (B): the Fifth Korea National Health and Nutrition  
47  
48 181 Examination Survey (KNHANES V), 2010–2012, South Korea  
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52 183 **Figure 2** Predicted probabilities of being obese (and their 95% confidence intervals)  
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54 184 by education for each income level in women in a model with only main effects (A) and a  
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4 185 model with both main and interaction effects (B): the Fifth Korea National Health and  
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6 186 Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea  
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11 188 According to Figures 1 and 2, the predicted probabilities of being obese differed  
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13 189 greatly between Models 1 and 2 for each gender. Whether for men or for women, the pattern  
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15 190 of the changes in the predicted probability for each income level was uniform across  
16  
17 191 educational levels in Model 1 (the left panel in each figure), suggesting that the income  
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19 192 differences in obesity are constant towards higher education. However, according to Model 2  
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21 193 for each gender (the right panel in each figure), the pattern became very different from that in  
22  
23 194 Model 1 for each gender and showed clear gender differences. For example, for men, the  
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25 195 income difference in obesity was the largest in participants who did not go beyond  
26  
27 196 elementary school (0.130) and the smallest in junior high school graduates (0.024), whereas  
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29 197 for women, the income difference in obesity was the largest in junior high school graduates  
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31 198 (0.199), the second largest in participants who had at least a college education (0.126) and the  
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33 199 smallest in senior high school graduates (0.052). This suggests cautiously that unlike in  
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35 200 women, the income differences in obesity decreases towards higher education in men.  
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40 201 Meanwhile, with respect to the education difference in obesity, it was the largest in  
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42 202 participants who had income in the second lowest quartile (0.148), the second largest in those  
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44 203 with income in the third lowest quartile (0.147), and the smallest in participants who had  
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46 204 income in the lowest quartile (0.090); but for women, it was the largest in participants who  
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48 205 had income in the highest quartile (0.198), the second largest in participants who had income  
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50 206 in the lowest quartile (0.196), and the smallest in those with income in the second lowest  
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52 207 quartile (0.125). This suggests cautiously that the education differences in obesity show an  
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4 208 inverse U-shape with higher income in men, in a sharp contrast with women having a U-  
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6 209 shape.

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8 210 The Findings in men can be summarized as follows: 1) Although men in two income  
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10 211 categories (the second lowest quartile and the lowest quartile) had the highest and the lowest  
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12 212 predicted probabilities across all educational levels in Model 1 respectively, no income level  
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14 213 had these distinctions with respect to all educational levels in Model 2. 2) The education-  
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16 214 income group with the highest predicted probability according to Model 1 and 2 differed: it  
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18 215 was junior high school graduates with incomes in the second lowest quartile in Model 1  
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20 216 (predicted probability = 0.392), but it was junior high school graduates with incomes in the  
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22 217 lowest quartile in Model 2 (predicted probability = 0.414). 3) The education-income group  
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24 218 with the lowest predicted probability also differed between Models 1 and 2: it was  
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26 219 participants who did not go beyond elementary school and who had incomes in the lowest  
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28 220 quartile in Model 1 (predicted probability = 0.292), but it was those did not go beyond  
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30 221 elementary school and who had incomes in third lowest quartile in Model 2 (predicted  
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32 222 probability = 0.243). 4) The gradient (or range) between the highest and lowest predicted  
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34 223 probabilities was 0.099 in Model 1 but 0.172 in Model 2.

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39 224 Likewise, the findings in women can be summarized as follows. 1) Although women  
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41 225 in two income levels (the lowest quartile and the highest quartile) had the highest and the  
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43 226 lowest predicted probabilities across all educational levels in Model 1 respectively, no  
44  
45 227 income level had these distinctions in Model 2. 2) The education-income group with the  
46  
47 228 highest predicted probability differed between Models 1 and 2: it was junior high school  
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49 229 graduates with incomes in the lowest quartile in Model 1 (predicted probability = 0.370), but  
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51 230 it was participants who did not go beyond elementary school and who had incomes in the  
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53 231 lowest quartile in Model 2 (predicted probability = 0.487). 3) The education-income group

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4 232 with the lowest predicted probability was the same in Models 1 and 2: it was those with at  
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6 233 least a college education with incomes in the highest quartile in Model 1 (predicted  
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8 234 probability = 0.183) and Model 2 (predicted probability = 0.218). 4) The gradient in the  
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10 235 predicted probability was 0.187 in Model 1 and 0.269 in Model 2.  
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## 15 16 237 **DISCUSSION**

### 17 18 238 **Comparison to previous studies**

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20 239 As shown in previous papers,<sup>1-3</sup> most studies on the relationship between socioeconomic  
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22 240 status and obesity focused on the main-effect terms of variables, rather than both the main-  
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24 241 effect terms of variables and the interaction-effect terms between variables. Most of those  
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26 242 studies showed that socioeconomic status and obesity are negatively correlated in both men  
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28 243 and women in developed countries.  
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31 244 Meanwhile, the results of our study warn researchers considering only the main-  
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33 245 effect terms in studies of the associations of education and income with obesity to be very  
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35 246 careful about interpreting their results. The reasons are: 1) studies considering only the main-  
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37 247 effect terms may come to incorrect conclusions about the roles of education and income; 2)  
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39 248 those studies may lack information on how differently either education or income is  
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41 249 associated with obesity; 3) those studies may lack information on how the income differences  
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43 250 in obesity differ across education levels (or how the education differences in obesity differ  
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45 251 across income levels); and 4) those studies may result in the incorrect identification of the  
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47 252 education-income group having the highest risk of obesity.  
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51 253 According to the results of comparison between the results in models including only  
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53 254 main-effect term of every studied variable (Models 1) and those in models adding the  
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4 255 interaction-effect terms between all studied variables to Models 1 (Models 2) in our study,  
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6 256 first, regarding the roles of education and income, in Models 1, only the main-effect term of  
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8 257 education was significant in men and the main-effect terms of both education and income  
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10 258 were significant in women. Alternatively, in Models 2, the main-effect of income as well as  
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12 259 the interaction-effect term between education and income was significant in men and only the  
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14 260 main-effect term of education was significant in women. Second, the results of Models 2  
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16 261 provided specific information that in men, income played a role in its association with obesity  
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18 262 on its own as well as through its interaction with education, whereas education played a role  
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20 263 only through its interaction with income. In women, however, education played a role on its  
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22 264 own. Third, as for the question as to how the income differences in obesity differ across  
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24 265 education levels, the income differences in obesity were uniform across education levels in  
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26 266 Models 1 (the left panels in figures). However, according to the results of Models 2 (the right  
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28 267 panels in figures), the income differences in obesity were very different between education  
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30 268 levels and their gender differences were very clear. Finally, the sub-population of those with  
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32 269 the particular set of education and income levels with the highest (or lowest) risk of obesity  
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34 270 differed according to gender in both Models 1 and 2, as shown in each figure.

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36 271 These findings suggest that the aforementioned well-known negative association  
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38 272 between socioeconomic status and obesity should be re-examined using models incorporating  
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40 273 interaction-effect terms among various characteristics. Similar results were obtained with  
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42 274 regard to abdominal obesity as those reported here for general obesity (these results are  
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44 275 available on request).

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### 47 48 277 **Plausible mechanisms**

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50 278 Based on these results, this study aimed to answer the following three questions. First, who

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4 279 are the participants belonging to the particular set of education and income levels showing the  
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6 280 highest and lowest values of the predicted probabilities of being obese for each gender and  
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8 281 why social positioning leads women to show strong educational differences in models  
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10 282 accounting for joint income effects, whereas men show strong income differences alone and  
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12 283 in combination with education?  
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15 284 To examine this, we provided Supplementary Tables 1 and 2, which show the  
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17 285 distributions of sample characteristics by education and income for men and women,  
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19 286 respectively. For men, as shown in the right panel of Figure 1, the highest predicted  
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21 287 probability of being obese was shown in junior high school graduates with incomes in the  
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23 288 lowest quartile (predicted probability = 0.414), whereas the lowest predicted probability in  
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25 289 participants those who did not go beyond elementary school and who had incomes in third  
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27 290 lowest quartile (predicted probability = 0.243). Relative to the education-income group  
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29 291 showing the lowest predicted probability of being obese, the group showing the highest  
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31 292 predicted probability tended to have more than twice as high as proportion in participants  
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33 293 who were formerly married, participants who were never-married, residents in non-metro  
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35 294 urban areas, manual workers, participants surveyed in 2010, current smokers, participants  
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37 295 who had energy intake at a moderate level, participants who reported that their health was  
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39 296 very bad, participants having hypertension, and participants having diabetes (Supplementary  
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41 297 Table 1).  
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46 298 Likewise, for women, as shown in the right panel of Figure 2, the highest predicted  
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48 299 probability of being obese was shown in participants who did not go beyond elementary  
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50 300 school and who had incomes in the lowest quartile (predicted probability = 0.487), whereas  
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52 301 the lowest predicted probability in participants with at least a college education with incomes  
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54 302 in the highest quartile (predicted probability = 0.218). Compared to the education-income  
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4 303 group showing the lowest predicted probability of being obese, the group showing the highest  
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6 304 predicted probability tended to have more than twice as high as proportion in participant who  
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8 305 were formerly married, residents in rural areas, participants who were unemployed,  
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10 306 participants whose daily sleep duration were short, participants who reported that their stress  
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12 307 was very high, participants who reported that their health was very bad, participants having  
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14 308 hypertension, participants having dyslipidemia, and participants having diabetes  
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17 309 (Supplementary Table 2).

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20 310 This comparison suggests that a participant's belonging to a particular one of  
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22 311 different education-income groups (that is, a social position) is associated with a particular  
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24 312 risk of obesity. A variety of studies on social position have shown that one's social position  
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26 313 may be determined by either exogenously or endogenously.<sup>16 17</sup> An individual can be placed  
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28 314 in a social position (or social status) within a society before or at birth. This is called ascribed  
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30 315 status. Ascribed statuses, which differ across societies, exist in all societies. Ascribed statuses  
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32 316 depend on genetics, gender, age, race, or family characteristics. Alternately, an individual can  
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34 317 achieve his or her social position by his or her own efforts, which is called achieved status.  
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36 318 Achieved statuses are social position which he or she acquires after his or her birth as  
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38 319 consequences of the exercise of knowledge, ability and skill, personal perseverance, and  
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40 320 active interactions with others. Both education and income provides examples of social  
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42 321 position that may be either ascribed or achieved status. Meanwhile, when comparing men and  
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44 322 women, if education is more of an ascribed status rather than an achieved status, compared to  
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46 323 the income, then education is more likely to make a positive contribution to income in  
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48 324 women compared to that in men. Then the role of education on obesity may overtake that of  
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50 325 income on obesity in women compared to men. Meanwhile, income in combination with  
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52 326 education rather than education alone may influence the risk of obesity in men. It seems

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4 327 definite that further research is necessary to evaluate the relationship between social position  
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6 328 and obesity.  
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8 329 Second, with regard to its association with obesity, why does education sometimes  
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10 330 interact with income and why does the interaction differ by gender? This study believes that  
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12 331 two different factors may be involved in this issue. More education may discourage obesity  
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14 332 insofar as it promotes a more efficient use of health-related services and products<sup>18 19</sup> and an  
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16 333 enhanced sense of control and empowerment.<sup>20 21</sup> In addition, and less directly, more  
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18 334 education may contribute to a higher income, which may discourage obesity by increasing  
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20 335 access to higher quality food and better medical care.<sup>18 19</sup> However, in a subgroup of people  
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22 336 (e.g., men with certain sociocultural characteristics), a higher income may be positively  
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24 337 associated with obesity even though more education leads to higher income. Thus, more  
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26 338 education and a higher income may lead to a higher likelihood of being obese among this  
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28 339 subgroup of people. Meanwhile, it is interesting to note that gender may modify the effects of  
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30 340 education and income on one's health. Previous research has suggested that gender,<sup>22</sup> race,<sup>23</sup>  
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32 341 place<sup>23 24</sup> and their intersections<sup>25 26</sup> alter the effects of education and income on health. A  
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34 342 recent study compared race-gender groups to examine the effects of baseline education and  
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36 343 income on sustained health problems in five domains (depressive symptoms, insomnia,  
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38 344 physical inactivity, BMI, and self-rated health) using the Health and Retirement Study in the  
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40 345 US.<sup>25</sup> This study found that the interaction of race and gender changed the protective effects  
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42 346 of social determinants on sustained health problems such as insomnia, physical inactivity, and  
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44 347 BMI. Another study showed that gender modifies the effects of education and income on  
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46 348 psychosocial well-being of patients with chronic conditions.<sup>22</sup>  
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53 349 It is generally known that women with a high level of education tend to be more  
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55 350 worried about weight control than men with the same level of education.<sup>27</sup> This may be  
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4 351 because obese women may be more penalized with regard to employment opportunities,<sup>28</sup>  
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6 352 wage equality,<sup>29</sup> and finding marriage partners than obese men.<sup>30</sup> On the other hand, even  
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8 353 men with a high income tend to feel more comfortable being overweight than do women in  
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10 354 the same income group.<sup>31</sup> This can be explained in part by the notion of habitus and  
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12 355 Bourdieu's theory, which states that the body has a symbolic value in size and shape for  
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14 356 people, but that valuations of the body differ by gender.<sup>32 33</sup>

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17 357 Even in a developed society such as South Korea, men have more political and  
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19 358 economic influence and are the primary wage earners for families, and most jobs tend to be  
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21 359 awarded first to men. Gender differences in body image are also pronounced in South Korea:  
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23 360 according to an international study of body image and weight control in young, educated  
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25 361 adults, the age-adjusted prevalence of feeling overweight was the second lowest in Korean  
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27 362 men (14%) compared with that in men in the other 22 countries, but the prevalence of seeing  
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29 363 oneself as overweight was the highest in Korean women (77%).<sup>31</sup> Thus, local culture and  
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31 364 norms put greater pressure on women than on men to lose weight, as indicated in previous  
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33 365 studies.<sup>31 34 35</sup>

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36 366 As a third question to be raised from the results of this study, after including the  
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38 367 interaction-effect terms in this study, why did the predicted probabilities of being obese  
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40 368 follow erratic rather than uniform patterns for both education and income levels, and why  
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42 369 were there gender differences in this regard? One reason for the erratic patterns in the  
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44 370 predicted probabilities might be that education or income may interact with some other  
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46 371 covariate(s). For example, the association between obesity and income may be influenced by  
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48 372 stress level in men<sup>36</sup> and health behaviors caused by a high level of stress, such as smoking  
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50 373 cigarettes and drinking alcohol, thereby contributing to the positive association between  
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52 374 socioeconomic status and obesity in men.<sup>37 38</sup> Meanwhile, previous studies investigated the

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4 375 relationship among contextual factors (e.g. gender, race, class, and place), psychosocial  
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6 376 factors and obesity factors (e.g. obesity and BMI).<sup>39 40 41 42 43</sup> Using data from the Health and  
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8 377 Retirement Study in the US, a study showed that the association between sustained health  
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10 378 problems such as depression and obesity are not universal across race and gender groups.<sup>40</sup>  
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12 379 This suggests that culture connected to race and gender may influence cognitive and  
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14 380 emotional elements that are essential for the perception of obesity and associated weight  
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16 381 management behaviors.<sup>44</sup>

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19 382 Another reason may be that, although education or income interacts with a covariate,  
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21 383 different combinations between levels of education or income and covariate categories may  
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23 384 be differently associated with being obese.

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25 385 There are three potential reasons for the gender differences in the predicted  
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27 386 probabilities of being obese for both education and income levels. First, these gender  
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29 387 differences partly derive from gender differences in the covariates that interact with education  
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31 388 or income. For example, in the present study, educational level showed significant interaction  
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33 389 effects with residential area, excessive alcohol consumption, self-perceived stress, self-  
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35 390 perceived health, and survey year in men, whereas women's educational level interacted  
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37 391 significantly with age, marital status, housing status, hypertension, and diabetes (results not  
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39 392 shown). Second, although covariates interact with education or income in both men and  
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41 393 women, the magnitude of the interactions between the covariate categories and levels of  
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43 394 education or income might differ by gender. Previous studies showed that, unlike in women,  
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45 395 increased income does not result in an equivalent adaptation to healthier behaviors in men.<sup>45</sup>  
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47 396 Finally, there may be gender differences in the reverse causation between education or  
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49 397 income and obesity. For example, in certain patriarchal societies, girls with a health problem  
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51 398 may be less likely to have a high level of education than their male counterparts.<sup>46</sup>  
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**Strengths and limitations**

401 This study analyzed data from a nationally representative sample of South Korean adults,  
402 providing abundant information about anthropometric measures, socio-demographic  
403 characteristics, lifestyle behaviors, and medical conditions. Using a quantified prediction, this  
404 study shows what would happen if policies to reduce obesity prevalence did not consider  
405 complex interactions among the characteristics of individuals. Above all, this study is the first  
406 to address the association of socioeconomic status with obesity while considering both the  
407 main-effect term of every studied variable and the interaction-effect terms between all studied  
408 variables.

409 This study has several limitations. The cross-sectional study design precludes causal  
410 inferences about the relationship between socioeconomic status and obesity. Moreover, the  
411 data were collected a self-report survey, which may have resulted in measurement error and  
412 recall bias. Other potential covariates, such as genetics, social network, and parental obesity,  
413 were not included in analyses because these data were not available. Unobserved factors,  
414 such discount rate and risk aversion, may have influenced both socioeconomic status and  
415 body weight.<sup>47 48</sup> Finally, we also could not incorporate race and ethnicity into our analysis  
416 because the KNHANES did not include these data, and moreover, because the absolute  
417 majority of the population is of Korean ethnicity.<sup>49 50</sup>

**Public health implications**

420 From a policy perspective, it is of interest whether as a government attempts to  
421 provide people with the highest level of education, its actions can lead to a reduction in the  
422 prevalence of obesity and the socioeconomic gradient in such prevalence. Though caution is

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4 423 required when making policy predictions based on findings from cross-sectional data,  
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6 424 according to the findings of this study, the answer might be “no.” An enhanced governmental  
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8 425 educational policy that enables all men to complete the highest level of formal education  
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10 426 would reduce the gradient in the predicted probability of being obese by 53%, from 0.130 to  
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12 427 0.061, but would also increase the average predicted probability by 26%, from 0.287 to 0.362.  
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14 428 Conversely, the same enhanced educational policy in women would raise the gradient in the  
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16 429 predicted probability by 77%, from 0.071 to 0.126, but would lower the average predicted  
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18 430 probability by 36%, from 0.440 to 0.283. This suggests that, in order to meet both goals (low  
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20 431 prevalence of obesity and reduced gradient by socioeconomic status), educational policies  
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22 432 should be implemented in combination with other social policies, and these governmental  
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24 433 efforts should be differentiated by gender. These results may elicit a new debate about  
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26 434 whether educational policies should consider health consequences.<sup>51 52</sup> Meanwhile, some  
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28 435 cross-country studies have shown that the determinants of health particularly the effects of  
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30 436 social determinants are specific to countries and have emphasized the need for local studies  
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32 437 that inform local policies and programs.<sup>24 53 54</sup>  
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## 40 439 CONCLUSIONS

41  
42 440 This is the first study to investigate the association of socioeconomic status with obesity  
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44 441 while considering both the main-effect term of every studied variable and the interaction-  
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46 442 effect terms between all studied variables. This study highlights the importance of interaction  
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48 443 effects in studies of the associations of socioeconomic status with obesity. According to the  
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50 444 results, moving from models evaluating only main effects to models evaluating both main  
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52 445 and interaction effects may change the association of socioeconomic status with obesity, the  
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4 446 group with the highest likelihood of obesity, the gradient in the likelihood of obesity by  
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6 447 socioeconomic status, and gender differences in the associations of socioeconomic status with  
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8 448 obesity. These results suggest that studies on the association between socioeconomic status  
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10 449 and obesity should include interaction-effect terms for all characteristics and consider gender  
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12 450 differences, and that policy efforts to reduce obesity and the resulting socioeconomic  
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14 451 gradients should be established based on the results of those in-depth studies. Moreover,  
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16 452 further research is needed to examine whether these findings are valid in other sociocultural  
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19 453 settings.  
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WC conceived and designed the study, conducting the literature review and the statistical analysis, writing the paper. JK collected and managed the data. JK, SJL, SL, and RK participated in reviewing the literature and writing the paper.

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## Competing interests

None declared.

## Ethics approval

Institutional Review Board of Yonsei University Graduate School of Public Health.

## Provenance and peer review

Not commissioned; externally peer reviewed.

## Data sharing statement

The data used in this study are available from the Korean Centers for Disease Control and

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Prevention database.

For peer review only

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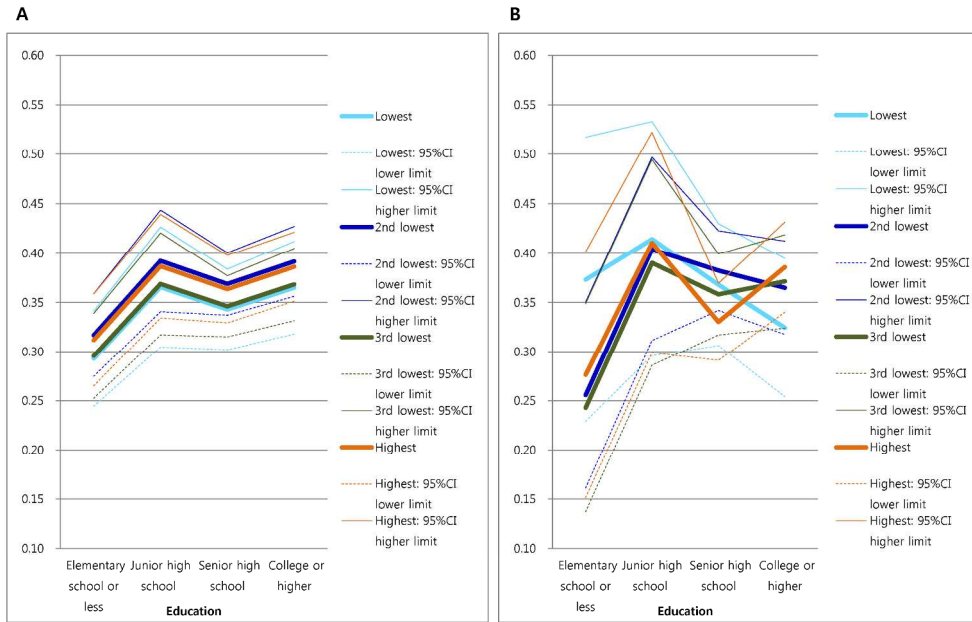


Figure 1 Predicted probabilities of being obese (and their 95% confidence intervals) by education for each income level in men in a model with only main effects (A) and a model with both main and interaction effects (B): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea

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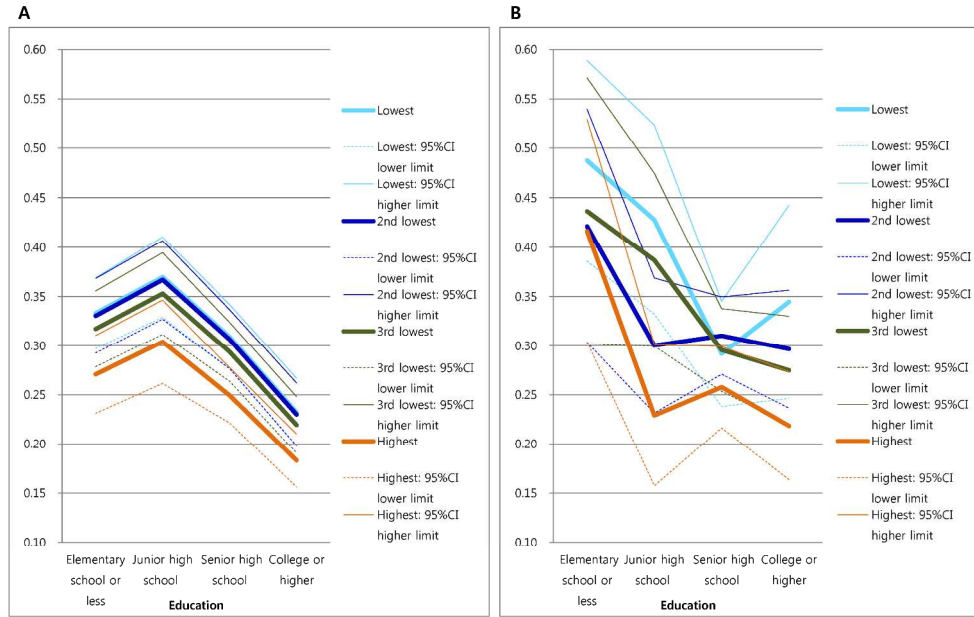


Figure 2 Predicted probabilities of being obese (and their 95% confidence intervals) by education for each income level in women in a model with only main effects (A) and a model with both main and interaction effects (B): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea

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**Table S1** Distribution (%) of sample characteristics in men by education and income (quartiles): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010-2012, South Korea

| Characteristic                   | Overall | Elementary school or less |         |         |      |        | Junior high school |         |         |      |        | Senior high school |         |         |      |        | College or more |         |         |      |        | (Total) |
|----------------------------------|---------|---------------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|-----------------|---------|---------|------|--------|---------|
|                                  |         | Low                       | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low             | 2nd low | 3rd low | High | (Sum)  |         |
| Age, years *                     | 50.8    | 70.5                      | 64.4    | 62.3    | 61.8 | (67.2) | 63.8               | 58.0    | 57.2    | 61.8 | 59.6   | 53.0               | 44.9    | 45.1    | 45.8 | 46.4   | 48.7            | 42.9    | 42.4    | 61.8 | 44.0   |         |
| Marital status                   |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Married                          | 79.7    | 10.6                      | 4.9     | 2.7     | 1.7  | (19.9) | 4.3                | 3.9     | 2.7     | 2.2  | (13.1) | 5.6                | 9.6     | 8.4     | 8.7  | (32.3) | 2.3             | 8.0     | 10.0    | 14.4 | (34.8) | (100.0) |
| Formerly married                 | 4.6     | 22.7                      | 8.9     | 1.8     | 2.1  | (35.4) | 11.2               | 4.1     | 2.1     | 2.4  | (19.8) | 11.5               | 7.1     | 4.7     | 5.5  | (26.8) | 5.3             | 3.8     | 4.1     | 4.7  | (18.0) | (100.0) |
| Never-married                    | 15.7    | 0.5                       | 0.4     | 0.1     | 0.0  | (1.0)  | 1.0                | 0.9     | 0.5     | 0.5  | (2.9)  | 9.7                | 16.2    | 14.0    | 15.8 | (55.7) | 5.7             | 8.3     | 11.7    | 14.8 | (40.5) | (100.0) |
| Residential area                 |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Metro urban                      | 44.2    | 6.1                       | 3.5     | 1.8     | 1.0  | (12.4) | 2.9                | 3.5     | 2.4     | 2.1  | (10.9) | 6.6                | 10.9    | 8.9     | 9.7  | (36.0) | 3.6             | 8.1     | 11.3    | 17.8 | (40.8) | (100.0) |
| Non-metro urban                  | 34.4    | 7.1                       | 3.7     | 1.7     | 1.4  | (14.0) | 4.0                | 3.0     | 2.0     | 1.6  | (10.6) | 6.0                | 10.7    | 10.9    | 10.2 | (37.8) | 2.6             | 9.8     | 11.4    | 14.0 | (37.7) | (100.0) |
| Rural                            | 21.4    | 20.5                      | 7.3     | 4.3     | 2.4  | (34.4) | 6.5                | 4.1     | 2.9     | 2.4  | (15.8) | 7.2                | 9.5     | 6.6     | 8.1  | (31.5) | 2.3             | 4.5     | 5.2     | 6.4  | (18.3) | (100.0) |
| Occupation,                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Unemployed                       | 25.6    | 9.8                       | 6.5     | 3.6     | 2.1  | (22.0) | 4.4                | 5.2     | 3.8     | 3.1  | (16.6) | 6.1                | 13.7    | 10.9    | 11.9 | (42.5) | 1.8             | 5.1     | 5.5     | 6.6  | (18.9) | (100.0) |
| Office worker                    | 26.8    | 0.3                       | 0.1     | 0.3     | 0.3  | (0.9)  | 0.4                | 0.3     | 0.5     | 0.8  | (1.8)  | 1.7                | 6.0     | 6.5     | 7.8  | (22.0) | 3.5             | 14.8    | 21.9    | 35.1 | (75.3) | (100.0) |
| Manual worker                    | 47.6    | 18.7                      | 5.0     | 2.0     | 1.4  | (27.0) | 7.3                | 3.5     | 1.5     | 1.1  | (13.5) | 12.5               | 9.4     | 8.4     | 7.0  | (37.2) | 4.6             | 5.9     | 6.0     | 5.8  | (22.3) | (100.0) |
| Housing status, home owner       | 76.4    | 9.9                       | 4.9     | 2.7     | 1.7  | (19.2) | 3.9                | 3.4     | 2.5     | 2.2  | (12.0) | 5.1                | 9.5     | 9.1     | 10.6 | (34.3) | 2.2             | 7.0     | 10.1    | 15.3 | (34.6) | (100.0) |
| Universal health insurance, NHI  | 98.2    | 9.1                       | 4.4     | 2.3     | 1.4  | (17.2) | 3.9                | 3.4     | 2.4     | 2.0  | (11.7) | 6.3                | 10.6    | 9.2     | 9.7  | (35.8) | 2.8             | 8.0     | 10.2    | 14.3 | (35.3) | (100.0) |
| Private health insurance, holder | 69.2    | 3.2                       | 3.0     | 2.1     | 1.5  | (9.7)  | 2.0                | 3.4     | 2.6     | 2.3  | (10.2) | 4.1                | 11.1    | 10.7    | 12.0 | (37.9) | 2.3             | 9.2     | 12.7    | 18.1 | (42.2) | (100.0) |
| Survey year                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| 2010                             | 35.3    | 9.7                       | 4.4     | 2.2     | 1.4  | (17.6) | 4.4                | 3.1     | 2.5     | 2.3  | (12.3) | 6.3                | 11.7    | 9.2     | 7.8  | (35.0) | 3.4             | 8.3     | 10.9    | 12.4 | (35.1) | (100.0) |
| 2011                             | 34.0    | 9.6                       | 4.2     | 2.1     | 1.6  | (17.5) | 3.7                | 4.2     | 2.2     | 2.0  | (12.0) | 5.9                | 10.0    | 8.9     | 10.8 | (35.6) | 2.5             | 8.2     | 9.0     | 15.2 | (34.8) | (100.0) |

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**Table S2** Distribution (%) of sample characteristics in women by education and income (quartiles): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010-2012, South Korea

| Characteristic                   | Overall | Elementary school or less |         |         |      |        | Junior high school |         |         |      |        | Senior high school |         |         |      |        | College or more |         |         |      |        | (Total) |
|----------------------------------|---------|---------------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|-----------------|---------|---------|------|--------|---------|
|                                  |         | Low                       | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low             | 2nd low | 3rd low | High | (Sum)  |         |
| Age, years *                     | 50.5    | 69.3                      | 64.2    | 63.4    | 64.9 | (67.0) | 59.6               | 55.4    | 54.9    | 54.6 | (56.2) | 43.7               | 41.4    | 42.9    | 43.0 | (42.6) | 38.5            | 35.9    | 36.2    | 39.1 | (37.5) |         |
| Marital status                   |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Married                          | 69.5    | 13.6                      | 6.8     | 4.0     | 3.0  | (27.3) | 2.6                | 3.6     | 3.1     | 2.8  | (12.1) | 3.6                | 10.5    | 9.3     | 10.5 | (33.9) | 1.2             | 5.9     | 7.8     | 11.8 | (26.7) | (100.0) |
| Formerly married                 | 18.2    | 45.2                      | 12.0    | 6.8     | 6.9  | (71.0) | 3.9                | 2.9     | 1.6     | 1.4  | (9.8)  | 6.3                | 4.2     | 2.1     | 2.2  | (14.9) | 1.3             | 0.9     | 1.1     | 1.0  | (4.3)  | (100.0) |
| Never-married                    | 12.3    | 0.3                       | 0.1     | 0.0     | 0.2  | (0.6)  | 0.5                | 0.3     | 0.2     | 0.1  | (1.1)  | 8.7                | 12.0    | 9.4     | 13.6 | (43.7) | 3.9             | 12.7    | 15.8    | 22.3 | (54.7) | (100.0) |
| Residential area                 |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Metro urban                      | 44.5    | 12.2                      | 5.8     | 3.6     | 2.6  | (24.3) | 2.5                | 3.0     | 2.4     | 2.4  | (10.3) | 5.3                | 9.9     | 8.0     | 10.9 | (34.1) | 1.7             | 6.5     | 8.8     | 14.2 | (31.3) | (100.0) |
| Non-metro urban                  | 35.0    | 13.9                      | 6.3     | 3.7     | 3.0  | (26.8) | 2.8                | 2.9     | 2.5     | 2.2  | (10.4) | 4.9                | 10.9    | 9.6     | 9.6  | (35.0) | 1.8             | 6.4     | 8.6     | 11.0 | (27.8) | (100.0) |
| Rural                            | 20.5    | 36.3                      | 10.2    | 5.5     | 5.4  | (57.4) | 2.5                | 3.5     | 2.5     | 1.8  | (10.3) | 3.4                | 6.5     | 5.1     | 5.7  | (20.7) | 0.7             | 3.5     | 3.0     | 4.4  | (11.6) | (100.0) |
| Occupation,                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Unemployed                       | 52.6    | 20.8                      | 9.5     | 5.5     | 5.0  | (40.8) | 2.9                | 4.8     | 4.5     | 4.1  | (16.2) | 5.0                | 10.8    | 8.9     | 9.2  | (33.9) | 0.8             | 2.5     | 2.3     | 3.6  | (9.2)  | (100.0) |
| Office worker                    | 16.0    | 0.4                       | 0.3     | 0.1     | 0.2  | (1.0)  | 0.4                | 0.9     | 0.2     | 0.5  | (2.0)  | 2.6                | 7.0     | 8.3     | 10.5 | (28.4) | 2.4             | 11.8    | 21.1    | 33.4 | (68.6) | (100.0) |
| Manual worker                    | 31.4    | 21.2                      | 7.3     | 4.3     | 3.3  | (36.2) | 3.1                | 2.7     | 2.0     | 1.6  | (9.3)  | 5.3                | 9.6     | 7.3     | 9.1  | (31.3) | 1.8             | 6.1     | 6.6     | 8.8  | (23.2) | (100.0) |
| Housing status, home owner       | 73.5    | 16.0                      | 7.8     | 4.7     | 4.0  | (32.5) | 2.3                | 3.1     | 2.9     | 2.6  | (10.8) | 3.2                | 8.5     | 8.3     | 10.8 | (30.8) | 1.2             | 5.2     | 7.3     | 12.2 | (25.9) | (100.0) |
| Universal health insurance, NHI  | 97.0    | 16.6                      | 7.0     | 4.1     | 3.4  | (31.1) | 2.5                | 3.1     | 2.5     | 2.3  | (10.4) | 4.3                | 9.7     | 8.2     | 9.6  | (31.8) | 1.6             | 6.0     | 7.8     | 11.4 | (26.7) | (100.0) |
| Private health insurance, holder | 70.7    | 7.7                       | 5.2     | 3.4     | 2.9  | (19.2) | 1.9                | 3.3     | 2.8     | 2.8  | (10.7) | 4.3                | 11.1    | 9.9     | 12.1 | (37.5) | 1.6             | 7.1     | 9.6     | 14.4 | (32.6) | (100.0) |
| Survey year                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| 2010                             | 34.0    | 17.1                      | 7.3     | 4.3     | 3.4  | (32.0) | 2.4                | 2.8     | 2.4     | 2.3  | (9.9)  | 4.9                | 10.5    | 7.9     | 8.2  | (31.5) | 1.6             | 6.0     | 8.2     | 10.8 | (26.6) | (100.0) |
| 2011                             | 34.1    | 18.1                      | 7.1     | 3.6     | 3.4  | (32.2) | 2.4                | 3.5     | 2.4     | 2.3  | (10.6) | 4.3                | 8.6     | 8.1     | 10.6 | (31.6) | 1.4             | 5.7     | 7.2     | 11.4 | (25.7) | (100.0) |

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## STROBE Statement—checklist of items that should be included in reports of observational studies

|                              | Item No | Recommendation  |
|------------------------------|---------|---|
| <b>Title and abstract</b>    | 1       | (a) Indicate the study's design with a commonly used term in the title or the abstract<br>→ We indicated it in the title and the abstract (page 1 and 3).   |
|                              |         | (b) Provide in the abstract an informative and balanced summary of what was done and what was found<br>→ We provided them in the abstract (pages 3-4).  |
| <b>Introduction</b>          |         |   |
| Background/rationale         | 2       | Explain the scientific background and rationale for the investigation being reported<br>→ We explained them in the introduction (pages 6-7).  |
| Objectives                   | 3       | State specific objectives, including any prespecified hypotheses<br>→ We stated them in the introduction (pages 6-7)  |
| <b>Methods</b>               |         |   |
| Study design                 | 4       | Present key elements of study design early in the paper<br>→ We presented them in the measures and variables section of the materials and methods (pages 8-9).  |
| Setting                      | 5       | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection<br>→ We described them in the data source and study sample sections of the materials and methods (pages 7-8).   |
| Participants                 | 6       | (a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up<br><i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls<br><b><i>Cross-sectional study</i></b> —Give the eligibility criteria, and the sources and methods of selection of participants<br>→ We presented them in the data source and study sample sections of the materials and methods (pages 7-8). |
|                              |         | (b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed<br><i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case<br>→ N/A   |
| Variables                    | 7       | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable<br>→ We clearly defined them in the measures and variables section of the materials and methods (pages 8-9).   |
| Data sources/<br>measurement | 8*      | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group.<br>→ We indicated them in the materials and methods (pages 7-11).   |
| Bias                         | 9       | Describe any efforts to address potential sources of bias   |

|                        |     |   |
|------------------------|-----|---|
|                        |     | → We described them in the strengths and limitations section of the discussion (page 29).   |
| Study size             | 10  | Explain how the study size was arrived at<br>→ We explained the study size in the data source and study sample section of the materials and methods (pages 7-8).  |
| Quantitative variables | 11  | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why<br>→ We explained quantitative variables' handling in the measures and variables section of the materials and methods (pages 8-9).   |
| Statistical methods    | 12  | (a) Describe all statistical methods, including those used to control for confounding<br>→ We described statistical methods in the analytic procedures section of the materials and methods (pages 9-11).<br>(b) Describe any methods used to examine subgroups and interactions<br>→ We described statistical methods in the analytic procedures section of the materials and methods (pages 9-11).<br>(c) Explain how missing data were addressed<br>→ N/A<br>(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed<br><i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed<br><b><i>Cross-sectional study</i></b> —If applicable, describe analytical methods taking account of sampling strategy<br>→ We described them in the analytic procedures section of the materials and methods (pages 9-11).<br>(e) Describe any sensitivity analyses<br>→ N/A |
| <b>Results</b>         |     |   |
| Participants           | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed<br>→ We reported them in the data source and study sample section of the materials and methods and in the table (pages 7-8, 12-15).<br>(b) Give reasons for non-participation at each stage<br>→ N/A<br>(c) Consider use of a flow diagram<br>→ N/A   |
| Descriptive data       | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders<br>→ We described them in the data source and study sample section of the materials and methods and in the table (pages 7-8, 12-15).<br>(b) Indicate number of participants with missing data for each variable of interest<br>→ N/A<br>(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)<br>→ N/A  |
| Outcome data           | 15* | <i>Cohort study</i> —Report numbers of outcome events or summary measures over time<br><i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure   |

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|--------------------------|----|---|
|                          |    | <b><u>Cross-sectional study</u></b> —Report numbers of outcome events or summary measures<br>→ We reported them in the table (pages 12-15; Table 1).  |
| Main results             | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included<br>→ We indicated them in the results and the table (pages 16-22, Table 2)<br>(b) Report category boundaries when continuous variables were categorized<br>→ We reported them in the measures and variables section of the materials and methods (pages 8-9).<br>(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period<br>→ N/A |
| Other analyses           | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses<br>→ N/A   |
| <b>Discussion</b>        |    |   |
| Key results              | 18 | Summarise key results with reference to study objectives<br>→ We indicated them in the comparison to previous studies section of the discussion (pages 22-23).  |
| Limitations              | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias<br>→ We discussed them in the strengths and limitations section of the discussion (page 29).   |
| Interpretation           | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence<br>→ We discussed them in the discussion (pages 22-30).  |
| Generalisability         | 21 | Discuss the generalisability (external validity) of the study results<br>→ We discussed it in the public health implications section of the discussion and in the conclusion (pages 29-30).   |
| <b>Other information</b> |    |   |
| Funding                  | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based<br>→ This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.  |

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Gender-specific interactions between education and income in relation to obesity: a cross-sectional analysis of the Fifth Korean National Health and Nutrition Examination Survey (KNHANES V)

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| Keywords:                       | Obesity, Education, Income, Gender, South Korea   |
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4 **Gender-specific interactions between education and income in**  
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6 **relation to obesity: a cross-sectional analysis of the Fifth Korean**  
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8 **National Health and Nutrition Examination Survey (KNHANES V)**  
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## 1 ABSTRACT

### 3 Objectives

4 To identify gender-specific associations between education and income in relation to obesity  
5 in developed countries by considering both the interaction-effect terms and the main-effect  
6 terms.

### 7 Design

8 A cross-sectional study. Education and income levels were chosen as socioeconomic status  
9 indicators. Socio-demographics, lifestyles and medical conditions were used as covariates in  
10 multivariable logistic regression models. Adjusted odds ratios and predicted probabilities of  
11 obesity were computed and adjusted for a complex survey design.

### 12 Setting

13 Data were obtained from the Fifth Korea National Health and Nutrition Examination Survey  
14 (2010-2012).

### 15 Participants

16 The sample included 7,337 male and 9,908 female participants aged 19 years or older.

### 17 Outcome measure

18 Obesity was defined as body mass index of 25 or more, according to a guideline for Asians.

### 19 Results

20 In models with no interaction-effect terms, only education was a significantly associated with  
21 obesity in men, but both income and education were significant in women. However, in  
22 models with the interaction-effect terms, income was significant in men but education was  
23 significant in women. The interaction effect between income and education was significant in

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4 24 men but not in women. Participants having the highest predicted probability of obesity over  
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6 25 educational and income levels differed between the two models, and between men and  
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8 26 women. The results of the predicted probabilities of obesity demonstrated that the highest  
9  
10 27 level of formal education for all men was associated with an increase in their predicted  
11  
12 28 probabilities of obesity by as much as 26%.

### 29 **Conclusions**

30 The well-known association between socioeconomic status and obesity may not be valid  
31 when interaction effects are included. Ignoring these effects and their gender differences may  
32 result in the targeting of wrong populations for reducing obesity prevalence and its resultant  
33 socioeconomic gradients. Further research is needed to examine whether these findings are  
34 valid in other sociocultural settings.

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4 36 **Article summary**

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7 37 **Strengths and limitations of this study**

- 8  
9 38 1. This is the first study to investigate the association of socioeconomic status with  
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11 39 obesity while considering both main effects and interaction effects.  
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13 40 2. This study analyzed data from a nationally representative sample of South Korean  
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15 41 adults, providing abundant information about anthropometric measures, socio-  
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17 42 demographic characteristics, lifestyle behaviors, and medical conditions.  
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19 43 3. This study shows by means of a quantified prediction what would happen if policies  
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21 44 to reduce obesity prevalence did not consider complex interactions among  
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23 45 characteristics of individuals.  
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25 46 4. The cross-sectional study design used in this study precludes causal inferences about  
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27 47 the relationship between socioeconomic status and obesity.  
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## 1 INTRODUCTION

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3 Numerous studies have investigated various factors related to obesity, and have identified  
4 associations between socioeconomic status and obesity, which are negatively correlated in  
5 both men and women in developed countries, although this is more consistent in women than  
6 in men.<sup>1-3</sup> However, because most empirical studies of obesity have ignored the interaction  
7 effects among various characteristics, these studies have failed to detect complex associations  
8 between different levels of socioeconomic status in relation to obesity; moreover, they have  
9 failed to explain differences among different population groups regarding the mechanisms  
10 through which socioeconomic status becomes associated with obesity.

11 For example, when the interaction effects among various characteristics are  
12 considered, previous studies have not answered the question as to whether the above-  
13 mentioned, well-known associations between socioeconomic status and obesity remain valid.  
14 Moreover, they have seldom explored why a socioeconomic status indicator sometimes  
15 interacts with another socioeconomic status indicator with regard to obesity, and whether the  
16 interaction differs by gender; whether the likelihood of being obese with regard to some  
17 levels of socioeconomic status remains the same before and after consideration of the  
18 interaction effects; and whether government can reduce the prevalence of obesity and change  
19 the socioeconomic gradient in the prevalence of this condition by providing all individuals  
20 with the highest level of socioeconomic status possible.

21 Attempting to fill the gap between previous findings and the unanswered questions,  
22 this study chose education and income levels as socioeconomic status indicators because they  
23 complement each other: educational level is established in early adulthood and tends to  
24 remain unchanged later in life, while income level may change throughout adult life. In

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4 25 particular, this study used data from South Korea, which has industrialized rapidly and is now  
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6 26 categorized as one of the ten largest advanced economies in the world.<sup>4</sup> Nevertheless, South  
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8 27 Korea is still noted for pronounced gender inequality almost everywhere, especially in the  
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10 28 labor markets.<sup>5 6</sup>

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13 29 This study considered two models for each gender: one that included only the main-  
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15 30 effect term of each variable, and the other included the two-way interaction-effect terms  
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17 31 between variables, as well as the main-effect term of each variable. Considering the complex  
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19 32 survey design, this study used multivariable logistic regression analyses to compute the odds  
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21 33 ratios of obesity and to predict the probability that a man or woman would be obese if he or  
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23 34 she had a particular set of education and income levels.  
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## 28 36 **MATERIALS AND METHODS**

### 29 37 **Data source and study sample**

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32 38 This study was based on the Fifth Korea National Health and Nutrition Examination Survey  
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34 39 (KNHANES V), 2010–2012, which used a stratified multistage clustered probability  
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36 40 sampling design to collect data on the non-institutionalized, civilian population of South  
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38 41 Korea on behalf of the Korean Centers for Disease Control and Prevention.<sup>7</sup> This survey was  
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40 42 composed of a health interview and a nutrition survey conducted at the participants' homes,  
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42 43 as well a physical examination conducted by physicians at designated examination centers.  
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44 44 Detailed information about the survey design and characteristics is available at the  
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46 45 KNHANES website.<sup>7</sup>

47 46 From KNHANES V, this study accessed data from a pool of 25,534 individuals  
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49 47 (8,958 in 2010, 8,518 in 2011, and 8,058 in 2012). Of this group, 24,173 had participated in  
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4 48 the interviews, and 18,571 individuals aged 19 years or older underwent physical  
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6 49 examinations. A total of 17,245 (92.86%) participants (7,337 men, 9,908 women) were  
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8 50 included in this study because they had the required information in their files. The ethical  
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10 51 review board of the educational institution where the research was conducted approved this  
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12 52 study.  
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### 18 54 **Measures and variables**

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20 55 The obesity status of each participant was determined anthropometrically using data from the  
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22 56 physical examination. Height was measured using a portable stadiometer, and body weight  
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24 57 was measured using a calibrated balance-beam scale, and the body mass index (BMI) was  
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26 58 calculated from these height and weight measurements. According to the guidelines proposed  
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28 59 by the World Health Organization indicating that Asians have a lower average BMI,<sup>8</sup> this  
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30 60 study defined general obesity as a BMI of at least 25. Also, because the percentage of  
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32 61 participants with BMI of less than 18.5 in the sample was very small (4.5%, 781 participants),  
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34 62 we combined participants with BMI of less than 18.5 and those with BMI between 18.5 to 25  
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36 63 into a single group. Therefore, a dichotomous outcome variable was constructed with a value  
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38 64 of 1 (obesity, BMI of 25 or higher) and 0 (non-obesity, BMI of less than 25).<sup>9-11</sup>  
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42 65 Levels of education and income were chosen as socioeconomic status indicators.  
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44 66 Education was defined as the highest level of formal education completed as of the date of  
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46 67 the interview. This study categorized education into four levels: elementary school or less,  
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48 68 junior high school, senior high school, and college or more. For income, this study used an  
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50 69 equivalized monthly household income calculation ( $[\text{monthly overall household income}]$   
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52 70  $[\text{household size}]^{-0.5}$ ) and divided the participants into four quartiles.  
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4 71 Nine sociodemographic characteristics, including gender, were incorporated as  
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6 72 covariates. Age was treated as a continuous variable, and marital status was categorized into  
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8 73 married, formerly married, and never married. Residential area was divided into metropolitan  
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10 74 urban area, non-metropolitan urban area, and rural area. Occupation was grouped into  
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12 75 unemployed, office worker, and manual worker. Housing status was coded in terms of  
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14 76 whether a participant was a renter or a home owner. Participants were categorized according  
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16 77 to whether they were enrolled in National Health Insurance or Medical Care Aid for regular  
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18 78 or low-income individuals, respectively, with regard to the universal health insurance  
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20 79 program. Participants with private health insurance were also noted. Survey year was added  
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22 80 to control for any fixed time effect.

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26 81 This study also incorporated ten characteristics about lifestyle and medical conditions.  
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28 82 Participants were grouped in terms of the following categories: 1) smoking, 2) excessive  
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30 83 alcohol consumption (at high risk due to drinking according to the gender-specific guidelines  
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32 84 of the World Health Organization),<sup>12</sup> 3) routinely exercising (physical activity as defined as  
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34 85 the participation in moderate or vigorous exercise for a respective frequency and duration),<sup>13</sup>  
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36 86 4) daily sleep duration (sleeping less than 7 h per day was defined as sleeping for a short  
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38 87 duration),<sup>14</sup> 5) daily energy intake (moderate energy intake was defined as total energy intake  
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40 88 within 1.25× of participants' estimated daily energy requirement),<sup>15</sup> 6) self-perceived stress, 7)  
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42 89 self-perceived health, 8) hypertension, 9) dyslipidemia, and 10) diabetes. The presence of the  
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44 90 last three chronic diseases was determined by a prior physician diagnosis at the pre-surgery  
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46 91 interview.

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### 50 51 52 53 93 **Analytic procedures**

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55 94 A six-fold analysis was performed. First, this study tested differences in the distributions of



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4 95 variables among men and women using the *t*-test for continuous variables and the  $\chi^2$  test for  
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6 96 categorical variables. Second, this study tested the association of each variable with obesity  
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8 97 by gender using the  $\chi^2$  test. Third, gender interaction effects were examined, for which simple  
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10 98 logistic regression models were constructed with main effects for gender and the variable of  
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12 99 interest as well as the interaction effects of the two variables. Due to the results, the  
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14 100 remaining analyses were stratified by gender.

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17 101 Fourth, to fit the multivariable logistic regression models, this study continued to re-  
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19 102 categorize each of the variables and defined each variable's reference category differently  
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21 103 until no strong multicollinearity was found for the main-effect models and no evidence of a  
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23 104 lack of goodness-of-fit was found in each model. The values for the variance inflation factor  
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25 105 were less than 3.65, and p-values based on the Hosmer-Lemeshow statistic were higher than  
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27 106 0.26.

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30 107 Fifth, this study estimated the adjusted odds ratios (ORs) of obesity and their 95%  
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32 108 confidence intervals (CIs) after fully adjusting for covariates. Two models were considered  
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34 109 for each gender: Model 1 included only the main-effect term of every variable, and Model 2  
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36 110 included the main-effect terms for each variable as well the two-way interaction-effect terms  
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38 111 between the variables. For the two-way interaction-effect terms between the variables, we  
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40 112 included interaction-effect terms between each pair of independent variables including  
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42 113 income, education, and 9 socio-demographic covariates. We considered not only the  
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44 114 interaction-effect terms between education and income, but also the interaction-effect terms  
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46 115 of each of the other independent variables. In order to identify a purer interaction-effect  
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48 116 between education and income in relation to obesity, we needed to control for other possible  
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50 117 variables that could influence obesity including 1) main effects of each independent variable,  
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52 118 2) interaction-effect terms between education and each of the 9 socio-demographic covariates,

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4 119 3) interaction-effect terms between income and each of the 9 socio-demographic covariates,  
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6 120 and 4) interaction-effect terms between each two of all 9 socio-demographic covariates. In  
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8 121 addition, the reasons why we considered the two-way interaction-effect terms between the  
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10 122 variables, rather than the three-way or greater interaction-effect terms, were: (1) as we  
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12 123 included three-way or greater interaction-effect terms, we had more difficulty having a  
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14 124 sufficient number of observations for the analyses in combined categories of independent  
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16 125 variables associated with the interactions, and (2) two-way interactions were sufficient to  
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18 126 emphasize the importance of gender-specific interactions between education and income in  
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20 127 relation to obesity.  
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24 128 Finally, to assess the association of each level of a socioeconomic status indicator  
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26 129 with obesity and to compare these associations across categories for both socioeconomic  
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28 130 status indicators, this study predicted the probability of a participant being obese (and its 95%  
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30 131 confidence intervals) if he or she had a particular set of education and income levels. These  
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32 132 probabilities, which were calculated by gender, denote the average of all participants'  
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34 133 probabilities if each participant belonged to a particular set of education and income levels,  
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36 134 while maintaining participant characteristics for the other variables constant.  
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39 135 All analyses and tests were conducted considering the sampling design of the survey.  
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41 136 However, for convenience, the descriptive statistics are shown as unweighted. P-values <  
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43 137 0.05 were considered statistically significance. The SAS 9.2 software (SAS Institute, Cary,  
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45 138 NC, USA) and STATA 12 software (StataCorp, College Station, TX, USA) were used to  
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47 139 perform all statistical analyses.  
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## 51 141 **RESULTS**

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4 142 **Descriptive statistics**  
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6 143 The rate of obesity was significantly higher in men (34.96%) than in women (29.67%), as  
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8 144 indicated by the significantly higher BMI in men than in women (Table 1). All characteristics  
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10 145 differed significantly by gender except for residential area, housing status, enrollment in a  
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12 146 private health insurance plan, survey year, daily sleep duration, and diabetes status.  
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148 **Table 1** Sample characteristics and their associations with obesity by gender: the Fifth Korea National Health and Nutrition Examination  
 149 Survey (KNHANES V), 2010-2012, South Korea

|                                       | Distribution, N (%) |              |          | Obesity, % |         |          |
|---------------------------------------|---------------------|--------------|----------|------------|---------|----------|
|                                       | Men                 | Women        | p Value† | Men        | Women   | p Value¶ |
| Body mass index, kg m <sup>-2</sup> * | 23.97 (3.1)         | 23.43 (3.6)  | <0.001   |            |         |          |
| Obesity                               | 2565 (35.0)         | 2940 (29.7)  | <0.001   |            |         |          |
| Age, years*                           | 50.79 (16.4)        | 50.48 (16.6) | <0.001   | 35.1‡      | 34.7‡   | <0.001   |
| Marital status                        |                     |              | <0.001   | <0.001§    | <0.001§ | <0.001   |
| Married                               | 5848 (79.7)         | 6887 (69.5)  |          | 36.0       | 30.5    |          |
| Formerly married                      | 339 (4.6)           | 1803 (18.2)  |          | 30.1       | 37.4    |          |
| Never-married                         | 1150 (15.7)         | 1218 (12.3)  |          | 31.0       | 13.4    |          |
| Residential area                      |                     |              | 0.446    | 0.259§     | <0.001§ | <0.001   |
| Metro urban                           | 3240 (44.2)         | 4404 (44.5)  |          | 35.2       | 27.0    |          |
| Non-metro urban                       | 2523 (34.4)         | 3471 (35.0)  |          | 36.6       | 29.2    |          |
| Rural                                 | 1574 (21.4)         | 2033 (20.5)  |          | 31.9       | 36.4    |          |
| Education                             |                     |              | <0.001   | <0.001§    | <0.001§ | <0.001   |
| Elementary school or less             | 1294 (17.6)         | 3168 (32.0)  |          | 26.6       | 40.2    |          |
| Junior high school                    | 867 (11.8)          | 1024 (10.3)  |          | 36.1       | 38.6    |          |
| Senior high school                    | 2617 (35.7)         | 3136 (31.7)  |          | 34.5       | 27.1    |          |
| College or more                       | 2559 (34.9)         | 2580 (26.0)  |          | 39.3       | 16.4    |          |
| Income, quartiles                     |                     |              | <0.001   | 0.002§     | <0.001§ | <0.001   |
| Lowest                                | 1694 (23.1)         | 2641 (26.6)  |          | 28.4       | 36.8    |          |
| 2nd lowest                            | 1924 (26.2)         | 2514 (25.4)  |          | 36.5       | 31.7    |          |
| 3rd lowest                            | 1739 (23.7)         | 2177 (22.0)  |          | 34.9       | 28.0    |          |

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| 4  |                            |             |             |        |         |         |        |
| 5  | Highest                    | 1980 (27.0) | 2576 (26.0) |        | 39.1    | 21.8    |        |
| 6  | Occupation                 |             |             | <0.001 | <0.001§ | <0.001§ | <0.001 |
| 7  | Unemployed                 | 1878 (25.6) | 5208 (52.6) |        | 28.7    | 31.1    |        |
| 8  | Office worker              | 1965 (26.8) | 1586 (16.0) |        | 42.1    | 17.5    |        |
| 9  | Manual worker              | 3494 (47.6) | 3114 (31.4) |        | 34.3    | 33.6    |        |
| 10 | Housing status             |             |             | 0.158  | 0.945§  | 0.843§  | 0.838  |
| 11 | Renter                     | 5606 (76.4) | 7280 (73.5) |        | 35.1    | 29.5    |        |
| 12 | Home owner                 | 1731 (23.6) | 2628 (26.5) |        | 34.6    | 30.1    |        |
| 13 | Universal health insurance |             |             | <0.001 | 0.020§  | 0.004§  | <0.001 |
| 14 | National Health Insurance  | 7204 (98.2) | 9609 (97.0) |        | 35.2    | 29.4    |        |
| 15 | Medical Care Aid           | 133 (1.8)   | 299 (3.0)   |        | 24.8    | 39.8    |        |
| 16 | Private health insurance   |             |             | 0.181  | <0.001§ | <0.001§ | <0.001 |
| 17 | Non-holder                 | 2258 (30.8) | 2898 (29.3) |        | 29.3    | 34.9    |        |
| 18 | Holder                     | 5079 (69.2) | 7010 (70.7) |        | 37.5    | 27.5    |        |
| 19 | Survey year                |             |             | 0.831  | 0.695§  | 0.133§  | 0.162  |
| 20 | 2010                       | 2592 (35.3) | 3364 (34.0) |        | 35.2    | 28.3    |        |
| 21 | 2011                       | 2494 (34.0) | 3380 (34.1) |        | 34.6    | 30.4    |        |
| 22 | 2012                       | 2251 (30.7) | 3164 (31.9) |        | 35.1    | 30.4    |        |
| 23 | Current smoking status     |             |             | <0.001 | 0.375§  | 0.936§  | 0.729  |
| 24 | Non-smoker                 | 4336 (59.1) | 9359 (94.5) |        | 36.1    | 29.8    |        |
| 25 | Smoker                     | 3001 (40.9) | 549 (5.5)   |        | 33.3    | 27.1    |        |
| 26 | Alcohol consumption        |             |             | <0.001 | <0.001§ | 0.064§  | <0.001 |
| 27 | Not excessive              | 4950 (67.5) | 8689 (87.7) |        | 31.5    | 30.1    |        |
| 28 | Excessive                  | 2387 (32.5) | 1219 (12.3) |        | 42.1    | 26.7    |        |
| 29 | Routine physical exercise  |             |             | <0.001 | 0.838§  | <0.001§ | 0.012  |

|    |                        |             |             |        |         |         |        |
|----|------------------------|-------------|-------------|--------|---------|---------|--------|
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| 3  |                        |             |             |        |         |         |        |
| 4  |                        |             |             |        |         |         |        |
| 5  | Physically active      | 1552 (21.2) | 1620 (16.4) |        | 35.6    | 32.8    |        |
| 6  | Physically inactive    | 5785 (78.8) | 8288 (83.6) |        | 34.8    | 29.1    |        |
| 7  |                        |             |             |        |         |         |        |
| 8  | Daily sleep duration   |             |             | 0.992  | 0.150§  | <0.001§ | 0.007  |
| 9  | Non-short              | 4291 (58.5) | 5717 (57.7) |        | 34.2    | 27.4    |        |
| 10 | Short                  | 3046 (41.5) | 4191 (42.3) |        | 36.0    | 32.8    |        |
| 11 |                        |             |             |        |         |         |        |
| 12 | Daily energy intake    |             |             | <0.001 | 0.818§  | <0.001§ | <0.001 |
| 13 | Not moderate           | 5859 (79.9) | 8306 (83.8) |        | 34.9    | 28.0    |        |
| 14 | Moderate               | 1478 (20.1) | 1602 (16.2) |        | 35.4    | 38.5    |        |
| 15 |                        |             |             |        |         |         |        |
| 16 | Self-perceived stress  |             |             | <0.001 | 0.969§  | 0.031§  | 0.236  |
| 17 | Not very high          | 7087 (96.6) | 9421 (95.1) |        | 35.1    | 29.5    |        |
| 18 | Very high              | 250 (3.4)   | 487 (4.9)   |        | 32.4    | 33.3    |        |
| 19 |                        |             |             |        |         |         |        |
| 20 | Self-perceived health  |             |             | <0.001 | 0.362§  | <0.001§ | 0.002  |
| 21 | Not very bad           | 7159 (97.6) | 9467 (95.5) |        | 35.2    | 29.1    |        |
| 22 | Very bad               | 178 (2.4)   | 441 (4.5)   |        | 24.2    | 42.4    |        |
| 23 |                        |             |             |        |         |         |        |
| 24 | Hypertension           |             |             | <0.001 | <0.001§ | <0.001§ | <0.001 |
| 25 | No                     | 5764 (78.6) | 7713 (77.8) |        | 32.6    | 24.3    |        |
| 26 | Yes                    | 1573 (21.4) | 2195 (22.2) |        | 43.6    | 48.5    |        |
| 27 |                        |             |             |        |         |         |        |
| 28 | Dyslipidemia           |             |             | <0.001 | <0.001§ | <0.001§ | 0.137  |
| 29 | No                     | 6859 (93.5) | 9065 (91.5) |        | 33.9    | 27.8    |        |
| 30 | Yes                    | 478 (6.5)   | 843 (8.5)   |        | 50.6    | 49.8    |        |
| 31 |                        |             |             |        |         |         |        |
| 32 | Diabetes               |             |             | 0.099  | 0.858§  | <0.001§ | <0.001 |
| 33 | No                     | 6661 (90.8) | 9219 (93.0) |        | 34.8    | 28.1    |        |
| 34 | Yes                    | 676 (9.2)   | 689 (7.0)   |        | 36.1    | 50.4    |        |
| 35 |                        |             |             |        |         |         |        |
| 36 | Number of participants | 7337        | 9908        |        | 7337    | 9908    |        |

N, number; All P-values were estimated by considering a stratified cluster sampling design.

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\*Mean (standard deviation).

†P-value was estimated by using the t-test for continuous variables and  $\chi^2$  tests for categorical variables.

‡For the continuous age variable, the proportion of obesity was obtained from people aged 50-59 years to which median age for each gender belonged.

§P-value was estimated by  $\chi^2$  tests for each gender.

¶P-value was estimated from the interaction effects terms between gender and each characteristic by using the logistic analysis.

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### 151 **Characteristics associated with obesity and gender differences**

152 Among men, the rate of obesity was significantly higher in participants who were married,  
153 had at least a college education, had an income in the highest quartile, had an office job, were  
154 National Health Insurance beneficiaries, had a private health insurance plan, consumed  
155 excessive alcohol, had hypertension, and had dyslipidemia (Table 1).

156 Among women, a significantly higher rate of obesity was observed in participants  
157 who were formerly married, lived in a rural area, did not go beyond elementary school, had  
158 incomes in the lowest quartile, were manual workers, were Medical Care Aid beneficiaries,  
159 had no private health insurance plan, were physically active, lacked adequate sleep, had  
160 moderate energy intake, reported very high levels of stress, had very poor self-perceived  
161 health, had hypertension, had dyslipidemia, and were diabetic. The rate of obesity differed  
162 significantly by gender with regard to all variables except for housing status, survey year,  
163 current smoking status, self-perceived stress, and had dyslipidemia.

### 165 **Adjusted associations of obesity with education and income**

166 Among men, according to the model with only main-effect terms (Model 1), the OR of  
167 obesity was 1.41 (95% CI = 1.12–1.77) in those with at least a college education compared  
168 with their counterparts who did not go beyond elementary school (Table 2). Conversely,  
169 according to the model with interaction-effect terms (Model 2), the OR was 0.05 (95% CI =  
170 0.01–0.32) among those with incomes in the highest quartile compared with those with  
171 incomes in the lowest quartile. Education alone was not significant. In terms of their  
172 association with obesity, education and income were found to interact with each other, as five  
173 combinations of educational and income levels were significant compared with their  
174 respective reference combinations.



175 **Table 2** Adjusted associations of education and income with obesity by gender: the Fifth Korea National Health and Nutrition Examination  
 176 Survey (KNHANES V), 2010-2012, South Korea

|                                  | Men (N=7337)       |                    | Women (N=9908)      |                    |
|----------------------------------|--------------------|--------------------|---------------------|--------------------|
|                                  | Model 1†           | Model 2‡           | Model 1†            | Model 2‡           |
|                                  | OR (95% CI)        | OR (95% CI)        | OR (95% CI)         | OR (95% CI)        |
| <b>Main effects</b>              |                    |                    |                     |                    |
| Education                        |                    |                    |                     |                    |
| Elementary school or less (EDU1) | 1.00               | 1.00               | 1.00                | 1.00               |
| Junior high school (EDU2)        | 1.41** (1.10-1.82) | 0.61 (0.06-6.56)   | 1.19 (0.98-1.44)    | 0.16* (0.03-0.89)  |
| Senior high school (EDU3)        | 1.27* (1.03-1.58)  | 0.57 (0.08-4.25)   | 0.89 (0.72-1.09)    | 0.13** (0.03-0.58) |
| College or more (EDU4)           | 1.41** (1.12-1.77) | 1.45 (0.16-13.04)  | 0.59*** (0.46-0.75) | 0.13* (0.02-0.89)  |
| Income, quartiles                |                    |                    |                     |                    |
| Lowest (INC1)                    | 1.00               | 1.00               | 1.00                | 1.00               |
| 2nd lowest (INC2)                | 1.13 (0.91-1.39)   | 0.11* (0.02-0.64)  | 0.99 (0.84-1.16)    | 1.13 (0.26-4.98)   |
| 3rd lowest (INC3)                | 1.01 (0.81-1.28)   | 0.18 (0.03-1.11)   | 0.93 (0.77-1.11)    | 1.16 (0.22-6.20)   |
| Highest (INC4)                   | 1.10 (0.87-1.39)   | 0.05** (0.01-0.32) | 0.73** (0.60-0.89)  | 1.58 (0.30-8.38)   |
| <b>Interaction effects</b>       |                    |                    |                     |                    |
| Education x Income               |                    |                    |                     |                    |
| EDU2 x INC2                      |                    | 1.91 (0.91-4.04)   |                     | 0.77 (0.44-1.33)   |
| EDU2 x INC3                      |                    | 1.88 (0.81-4.34)   |                     | 1.11 (0.60-2.06)   |

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|-------------------------------|-------------------|------------------|-------|-------|
| EDU2 x INC4                   | 1.72 (0.65-4.59)  | 0.51 (0.26-1.01) |       |       |
| EDU3 x INC2                   | 2.30* (1.17-4.52) | 1.58 (0.90-2.75) |       |       |
| EDU3 x INC3                   | 2.17* (1.05-4.47) | 1.34 (0.73-2.47) |       |       |
| EDU3 x INC4                   | 1.52 (0.67-3.44)  | 1.23 (0.67-2.24) |       |       |
| EDU4 x INC2                   | 2.74* (1.14-6.56) | 1.08 (0.49-2.39) |       |       |
| EDU4 x INC3                   | 3.00* (1.27-7.12) | 0.87 (0.38-2.00) |       |       |
| EDU4 x INC4                   | 2.65* (1.04-6.78) | 0.66 (0.27-1.58) |       |       |
| Hosmer-Lemeshow test, p Value | 0.967             | 0.530            | 0.304 | 0.471 |

N, number; OR, odds ratio; CI, confidence interval; All models were adjusted for age, marital status, residential area, occupation, housing status, universal health insurance, private health insurance, survey year, smoking, alcohol consumption, routine physical exercise, daily sleep duration, daily energy intake, self-perceived stress, self-perceived health, hypertension, dyslipidemia, and diabetes; All estimates were obtained by considering a stratified cluster sampling design.

\* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

†Models 1 included only main effects terms for all variables.

‡Models 2 included both main effects terms and two-way interaction effects terms for all variables.

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4 177 Among women, according to Model 1, the OR was 0.59 (95% CI = 0.46–0.75) in  
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6 178 participants who had at least a college education compared with those who did not go beyond  
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8 179 elementary school, and 0.73 (95% CI = 0.60–0.89) among those with incomes in the highest  
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10 180 quartile compared with those with incomes in the lowest quartile. In contrast, according to  
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12 181 Model 2, the OR was 0.13 (95% CI = 0.02–0.89) among participants with at least a college  
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14 182 education compared with participants who did not go beyond elementary school. Income  
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16 183 alone was not significant. In terms of an interaction effect, one combination of educational  
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18 184 and income levels was marginally significant relative to the reference combination  
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21 185 ( $p = 0.053$ ).  
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### 26 187 **Predicted probability of being obese**

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28 188 The predicted probabilities for a participant to be obese if he or she had a particular set of  
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30 189 education and income levels were obtained from the model with only the main-effect term of  
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32 190 each independent variable (Model 1) and from the model with both the main-effect term of  
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34 191 each independent variable as well as the two-way interaction-effect terms between  
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36 192 independent variables (Model 2); these results are displayed graphically in Figures 1 and 2  
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38 193 for men and women, respectively.  
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44 195 **Figure 1** Predicted probabilities of being obese (and their 95% confidence intervals)  
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46 196 by education for each income level in men in a model with only main effects (A) and a model  
47  
48 197 with both main and interaction effects (B): the Fifth Korea National Health and Nutrition  
49  
50 198 Examination Survey (KNHANES V), 2010–2012, South Korea  
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54 200 **Figure 2** Predicted probabilities of being obese (and their 95% confidence intervals)  
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4 201 by education for each income level in women in a model with only main effects (A) and a  
5 202 model with both main and interaction effects (B): the Fifth Korea National Health and  
6 203 Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea  
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13 205 According to Figures 1 and 2, the predicted probabilities of being obese differed  
14 206 greatly between Models 1 and 2 for each gender. Whether for men or for women, the pattern  
15 207 of the changes in the predicted probability for each income level was uniform across  
16 208 educational levels in Model 1 (the left panel in each figure), suggesting that the income  
17 209 differences in obesity are constant towards higher education. However, according to Model 2  
18 210 for each gender (the right panel in each figure), the pattern became very different from that in  
19 211 Model 1 for each gender and showed clear gender differences. For example, for men, the  
20 212 income difference in obesity was the largest in participants who did not go beyond  
21 213 elementary school (0.130) and the smallest in junior high school graduates (0.024), whereas  
22 214 for women, the income difference in obesity was the largest in junior high school graduates  
23 215 (0.199), the second largest in participants who had at least a college education (0.126) and the  
24 216 smallest in senior high school graduates (0.052). This suggests cautiously that unlike in  
25 217 women, the income differences in obesity decreases towards higher education in men.  
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42 218 Meanwhile, with respect to the education difference in obesity, it was the largest in  
43 219 participants who had income in the second lowest quartile (0.148), the second largest in those  
44 220 with income in the third lowest quartile (0.147), and the smallest in participants who had  
45 221 income in the lowest quartile (0.090); but for women, it was the largest in participants who  
46 222 had income in the highest quartile (0.198), the second largest in participants who had income  
47 223 in the lowest quartile (0.196), and the smallest in those with income in the second lowest  
48 224 quartile (0.125). This suggests cautiously that the education differences in obesity show an  
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4 225 inverse U-shape with higher income in men, in a sharp contrast with women having a U-  
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6 226 shape.  
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8  
9 227 The Findings in men can be summarized as follows: 1) Although men in two income  
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11 228 categories (the second lowest quartile and the lowest quartile) had the highest and the lowest  
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13 229 predicted probabilities across all educational levels in Model 1 respectively, no income level  
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15 230 had these distinctions with respect to all educational levels in Model 2. 2) The education-  
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17 231 income group with the highest predicted probability according to Model 1 and 2 differed: it  
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19 232 was junior high school graduates with incomes in the second lowest quartile in Model 1  
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21 233 (predicted probability = 0.392), but it was junior high school graduates with incomes in the  
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23 234 lowest quartile in Model 2 (predicted probability = 0.414). 3) The education-income group  
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25 235 with the lowest predicted probability also differed between Models 1 and 2: it was  
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27 236 participants who did not go beyond elementary school and who had incomes in the lowest  
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29 237 quartile in Model 1 (predicted probability = 0.292), but it was those did not go beyond  
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31 238 elementary school and who had incomes in third lowest quartile in Model 2 (predicted  
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33 239 probability = 0.243). 4) The gradient (or range) between the highest and lowest predicted  
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35 240 probabilities was 0.099 in Model 1 but 0.172 in Model 2.  
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39 241 Likewise, the findings in women can be summarized as follows. 1) Although women  
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41 242 in two income levels (the lowest quartile and the highest quartile) had the highest and the  
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43 243 lowest predicted probabilities across all educational levels in Model 1 respectively, no  
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45 244 income level had these distinctions in Model 2. 2) The education-income group with the  
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47 245 highest predicted probability differed between Models 1 and 2: it was junior high school  
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49 246 graduates with incomes in the lowest quartile in Model 1 (predicted probability = 0.370), but  
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51 247 it was participants who did not go beyond elementary school and who had incomes in the  
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53 248 lowest quartile in Model 2 (predicted probability = 0.487). 3) The education-income group  
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4 249 with the lowest predicted probability was the same in Models 1 and 2: it was those with at  
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6 250 least a college education with incomes in the highest quartile in Model 1 (predicted  
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8 251 probability = 0.183) and Model 2 (predicted probability = 0.218). 4) The gradient in the  
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10 252 predicted probability was 0.187 in Model 1 and 0.269 in Model 2.  
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## 15 16 254 **DISCUSSION**

### 17 18 255 **Comparison to previous studies**

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20 256 As shown in previous papers,<sup>1-3</sup> most studies on the relationship between socioeconomic  
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22 257 status and obesity focused on the main-effect terms of independent variables, rather than both  
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24 258 the main-effect terms of the variables and the interaction-effect terms between the variables.  
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26 259 Most of those studies indicated that socioeconomic status and obesity are negatively  
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28 260 correlated in both men and women in developed countries.  
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32 261 However, our study suggests that in certain developed countries like South Korea,  
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34 262 education and income, which are major socioeconomic status indicators, may not have  
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36 263 negative associations with obesity in either men or women and they may have somewhat  
37  
38 264 complex relationships with obesity.  
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41 265 This suggestion is depicted clearly in both Table 2 and Figures. Comparing the  
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43 266 results shown in Table 2, first, we may be informed about the different roles of education and  
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45 267 income in relations to obesity between the models, including only main-effect term of all  
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47 268 independent variables considered in this study (Models 1) and models adding the two-way  
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49 269 interaction-effect terms between the independent variables to Models 1 (Models 2). In  
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51 270 Models 1, only the main-effect term of education was significant in men and the main-effect  
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53 271 terms of both education and income were significant in women. By contrast, in Models 2, the  
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4 272 main-effect of income as well as the interaction-effect term between education and income  
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6 273 was significant in men, but only the main-effect term of education was significant in women.  
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8 274 If we interpret the results of Models 2, it seems that in men, education plays a role only  
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10 275 through its interaction with income, whereas income plays a role in its association with  
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12 276 obesity on its own as well as through its interaction with education; in women, however,  
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14 277 education plays a role in its association with obesity on its own, despite no role of income.  
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17 278 Complex relationships between each of education and income with obesity could be  
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19 279 displayed through Figures 1 and 2. As for a question as to how the income differences in  
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21 280 obesity differ across education levels, the income differences in obesity were uniform across  
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23 281 education levels in Models 1 (the left panels in figures). However, in Models 2 (the right  
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25 282 panels in figures), the income differences in obesity were very clearly different between  
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27 283 education levels and their gender differences. In addition, as shown in each figure, the sub-  
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29 284 population of those with a particular set of education and income levels with the highest (or  
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31 285 lowest) risk of obesity differed according to gender in both Models 1 and 2.  
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35 286 Therefore, the results of our study may caution researchers considering only the  
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37 287 main-effect terms in studies of the associations of education and income with obesity to be  
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39 288 very careful about interpreting their results. The reasons are: 1) studies considering only the  
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41 289 main-effect terms may come to incorrect conclusions about the roles of education and income;  
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43 290 2) those studies may lack information on how differently either education or income is  
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45 291 associated with obesity; 3) those studies may lack information on how the income differences  
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47 292 in obesity differ across education levels (or how the education differences in obesity differ  
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49 293 across income levels); and 4) those studies may result in the incorrect identification of the  
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51 294 education-income group having the highest risk of obesity.  
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55 295 In addition, according to the results of our study, the aforementioned well-known

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4 296 negative association between socioeconomic status and obesity should be re-examined using  
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6 297 models incorporating interaction-effect terms among various characteristics. Similar results  
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8 298 were obtained with regard to abdominal obesity as those reported here for general obesity  
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11 299 (these results are available on request).  
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### 14 301 **Plausible mechanisms**

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17 302 Based on these results, this study aimed to answer the following three questions. First, who  
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19 303 are the participants belonging to the particular set of education and income levels showing the  
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21 304 highest and lowest values of the predicted probabilities of being obese for each gender and  
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23 305 why social positioning leads women to show strong educational differences in models  
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25 306 accounting for joint income effects, whereas men show strong income differences alone and  
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27 307 in combination with education?  
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31 308 To examine this, we provided Supplementary Tables 1 and 2, which show the  
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33 309 distributions of sample characteristics by education and income for men and women,  
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35 310 respectively. For men, as shown in the right panel of Figure 1, the highest predicted  
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37 311 probability of being obese was shown in junior high school graduates with incomes in the  
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39 312 lowest quartile (predicted probability = 0.414), whereas the lowest predicted probability in  
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41 313 participants those who did not go beyond elementary school and who had incomes in third  
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43 314 lowest quartile (predicted probability = 0.243). Relative to the education-income group  
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45 315 showing the lowest predicted probability of being obese, the group showing the highest  
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47 316 predicted probability tended to have more than twice as high as proportion in participants  
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49 317 who were formerly married, participants who were never-married, residents in non-metro  
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51 318 urban areas, manual workers, participants surveyed in 2010, current smokers, participants  
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53 319 who had energy intake at a moderate level, participants who reported that their health was  
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4 320 very bad, participants having hypertension, and participants having diabetes (Supplementary  
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6 321 Table 1).

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8 322 Likewise, for women, as shown in the right panel of Figure 2, the highest predicted  
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10 323 probability of being obese was shown in participants who did not go beyond elementary  
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12 324 school and who had incomes in the lowest quartile (predicted probability = 0.487), whereas  
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14 325 the lowest predicted probability in participants with at least a college education with incomes  
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16 326 in the highest quartile (predicted probability = 0.218). Compared to the education-income  
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18 327 group showing the lowest predicted probability of being obese, the group showing the highest  
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20 328 predicted probability tended to have more than twice as high as proportion in participant who  
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22 329 were formerly married, residents in rural areas, participants who were unemployed,  
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24 330 participants whose daily sleep duration were short, participants who reported that their stress  
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26 331 was very high, participants who reported that their health was very bad, participants having  
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28 332 hypertension, participants having dyslipidemia, and participants having diabetes  
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31 333 (Supplementary Table 2).

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35 334 This comparison suggests that a participant's belonging to a particular one of  
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37 335 different education-income groups (that is, a social position) is associated with a particular  
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39 336 risk of obesity. A variety of studies on social position have shown that one's social position  
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41 337 may be determined exogenously or endogenously.<sup>16 17</sup> An individual can be placed in a social  
42  
43 338 position (or social status) within a society before or at birth. This is called ascribed status.  
44  
45 339 Ascribed statuses, which differ across societies, exist in all societies. Ascribed statuses  
46  
47 340 depend on genetics, gender, age, race, or family characteristics. Alternately, an individual can  
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49 341 achieve his or her social position by his or her own efforts, which is called achieved status.  
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51 342 Achieved statuses are social position which he or she acquires after his or her birth as  
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53 343 consequences of the exercise of knowledge, ability and skill, personal perseverance, and

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4 344 active interactions with others. Both education and income provides examples of social  
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6 345 position that may be either ascribed or achieved status. Meanwhile, when comparing men and  
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8 346 women, if education is more of an ascribed status rather than an achieved status, compared to  
9  
10 347 the income, then education is more likely to make a positive contribution to income in  
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12 348 women compared to that in men. Then the role of education on obesity may overtake that of  
13  
14 349 income on obesity in women compared to men. Meanwhile, income in combination with  
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16 350 education rather than education alone may influence the risk of obesity in men. It seems  
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18 351 definite that further research is necessary to evaluate the relationship between social position  
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20 352 and obesity.  
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24 353         Second, with regard to its association with obesity, why does education sometimes  
25  
26 354 interact with income and why does the interaction differ by gender? This study believes that  
27  
28 355 two different factors may be involved in this issue. More education may discourage obesity  
29  
30 356 insofar as it promotes a more efficient use of health-related services and products<sup>18 19</sup> and an  
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32 357 enhanced sense of control and empowerment.<sup>20 21</sup> In addition, and less directly, more  
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34 358 education may contribute to a higher income, which may discourage obesity by increasing  
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36 359 access to higher quality food and better medical care.<sup>18 19</sup> However, in a subgroup of people  
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38 360 (e.g., men with certain sociocultural characteristics), a higher income may be positively  
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40 361 associated with obesity even though more education leads to higher income. Thus, more  
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42 362 education and a higher income may lead to a higher likelihood of being obese among this  
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44 363 subgroup of people. Meanwhile, it is interesting to note that gender may modify the effects of  
45  
46 364 education and income on one's health. Previous research has suggested that gender,<sup>22</sup> race,<sup>23</sup>  
47  
48 365 place<sup>23 24</sup> and their intersections<sup>25 26</sup> alter the effects of education and income on health. A  
49  
50 366 recent study compared race-gender groups to examine the effects of baseline education and  
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52 367 income on sustained health problems in five domains (depressive symptoms, insomnia,  
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4 368 physical inactivity, BMI, and self-rated health) using the Health and Retirement Study in the  
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6 369 US.<sup>25</sup> This study found that the interaction of race and gender changed the protective effects  
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8 370 of social determinants on sustained health problems such as insomnia, physical inactivity, and  
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10 371 BMI. Another study showed that gender modifies the effects of education and income on  
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12 372 psychosocial well-being of patients with chronic conditions.<sup>22</sup>

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14  
15 373 It is generally known that women with a high level of education tend to be more  
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17 374 worried about weight control than men with the same level of education.<sup>27</sup> This may be  
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19 375 because obese women may be more penalized with regard to employment opportunities,<sup>28</sup>  
20  
21 376 wage equality,<sup>29</sup> and finding marriage partners than obese men.<sup>30</sup> On the other hand, even  
22  
23 377 men with a high income tend to feel more comfortable being overweight than do women in  
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25 378 the same income group.<sup>31</sup> This can be explained in part by the notion of habitus and  
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27 379 Bourdieu's theory, which states that the body has a symbolic value in size and shape for  
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29 380 people, but that valuations of the body differ by gender.<sup>32 33</sup>

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33 381 Even in a developed society such as South Korea, men have more political and  
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35 382 economic influence and are the primary wage earners for families, and most jobs tend to be  
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37 383 awarded first to men. Gender differences in body image are also pronounced in South Korea:  
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39 384 according to an international study of body image and weight control in young, educated  
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41 385 adults, the age-adjusted prevalence of feeling overweight was the second lowest in Korean  
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43 386 men (14%) compared with that in men in the other 22 countries, but the prevalence of seeing  
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45 387 oneself as overweight was the highest in Korean women (77%).<sup>31</sup> Thus, local culture and  
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47 388 norms put greater pressure on women than on men to lose weight, as indicated in previous  
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49 389 studies.<sup>31 34 35</sup>

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53 390 As a third question to be raised from the results of this study, after including the  
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55 391 interaction-effect terms in this study, why did the predicted probabilities of being obese

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4 392 follow erratic rather than uniform patterns for both education and income levels, and why  
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6 393 were there gender differences in this regard? One reason for the erratic patterns in the  
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8 394 predicted probabilities might be that education or income may interact with some other  
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10 395 covariate(s). For example, the association between obesity and income may be influenced by  
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12 396 stress level in men<sup>36</sup> and health behaviors caused by a high level of stress, such as smoking  
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14 397 cigarettes and drinking alcohol, thereby contributing to the positive association between  
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16 398 socioeconomic status and obesity in men.<sup>37 38</sup> Meanwhile, previous studies investigated the  
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18 399 relationship among contextual factors (e.g. gender, race, class, and place), psychosocial  
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21 400 factors and obesity factors (e.g. obesity and BMI).<sup>39 40 41 42 43</sup> Using data from the Health and  
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23 401 Retirement Study in the US, a study showed that the association between sustained health  
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25 402 problems such as depression and obesity are not universal across race and gender groups.<sup>40</sup>  
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27 403 This suggests that culture connected to race and gender may influence cognitive and  
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29 404 emotional elements that are essential for the perception of obesity and associated weight  
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31 405 management behaviors.<sup>44</sup>

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35 406 Another reason may be that, although education or income interacts with a covariate,  
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37 407 different combinations between levels of education or income and covariate categories may  
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39 408 be differently associated with being obese.

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42 409 There are three potential reasons for the gender differences in the predicted  
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44 410 probabilities of being obese for both education and income levels. First, these gender  
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46 411 differences partly derive from gender differences in the covariates that interact with education  
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48 412 or income. For example, in the present study, educational level showed significant interaction  
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50 413 effects with residential area, excessive alcohol consumption, self-perceived stress, self-  
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52 414 perceived health, and survey year in men, whereas women's educational level interacted  
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54 415 significantly with age, marital status, housing status, hypertension, and diabetes (results not

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4 416 shown). Second, although covariates interact with education or income in both men and  
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6 417 women, the magnitude of the interactions between the covariate categories and levels of  
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8 418 education or income might differ by gender. Previous studies showed that, unlike in women,  
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10 419 increased income does not result in an equivalent adaptation to healthier behaviors in men.<sup>45</sup>  
11  
12 420 Finally, there may be gender differences in the reverse causation between education or  
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14 421 income and obesity. For example, in certain patriarchal societies, girls with a health problem  
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16 422 may be less likely to have a high level of education than their male counterparts.<sup>46</sup>  
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### 22 424 **Strengths and limitations**

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24 425 This study analyzed data from a nationally representative sample of South Korean adults,  
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26 426 providing abundant information about anthropometric measures, socio-demographic  
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28 427 characteristics, lifestyle behaviors, and medical conditions. Using a quantified prediction, this  
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30 428 study shows what would happen if policies to reduce obesity prevalence did not consider  
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32 429 complex interactions among the characteristics of individuals. Above all, this study is the first  
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34 430 to address the association of socioeconomic status with obesity while considering both the  
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36 431 main-effect term of each independent variable and the two-way interaction-effect terms  
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38 432 between independent variables.  
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42 433 This study has several limitations. The cross-sectional study design precludes causal  
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44 434 inferences about the relationship between socioeconomic status and obesity. Moreover, the  
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46 435 data were collected by a self-report survey, which may have resulted in measurement error  
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48 436 and recall bias. Although it is beyond the scope of this study, it would be of great interest to  
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50 437 explore gender-specific interactions among education, income and other socioeconomic  
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52 438 status indicators like occupation, home-ownership and marital status. Other potential  
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54 439 covariates, such as genetics, social network, and parental obesity, were not included in  
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4 440 analyses because these data were not available. Unobserved factors, such discount rate and  
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6 441 risk aversion, may have influenced both socioeconomic status and body weight.<sup>47 48</sup> Finally,  
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8 442 we also could not incorporate race and ethnicity into our analysis because the KNHANES did  
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10 443 not include these data, and moreover, because the absolute majority of the population is of  
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12 444 Korean ethnicity.<sup>49 50</sup>  
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### 17 446 **Public health implications**

18  
19 447 From a policy perspective, it is of interest whether as a government attempts to  
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21 448 provide people with the highest level of education, its actions can lead to a reduction in the  
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23 449 prevalence of obesity and the socioeconomic gradient in such prevalence. Though caution is  
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25 450 required when making policy predictions based on findings from cross-sectional data,  
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27 451 according to the findings of this study, the answer might be “no.” An enhanced governmental  
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29 452 educational policy that enables all men to complete the highest level of formal education  
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31 453 would reduce the gradient in the predicted probability of being obese by 53%, from 0.130 to  
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33 454 0.061, but would also increase the average predicted probability by 26%, from 0.287 to 0.362.  
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35 455 Conversely, the same enhanced educational policy in women would raise the gradient in the  
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37 456 predicted probability by 77%, from 0.071 to 0.126, but would lower the average predicted  
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39 457 probability by 36%, from 0.440 to 0.283. This suggests that, in order to meet both goals (low  
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41 458 prevalence of obesity and reduced gradient by socioeconomic status), educational policies  
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43 459 should be implemented in combination with other social policies, and these governmental  
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45 460 efforts should be differentiated by gender. These results may elicit a new debate about  
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47 461 whether educational policies should consider health consequences.<sup>51 52</sup> Meanwhile, some  
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49 462 cross-country studies have shown that the determinants of health particularly the effects of  
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51 463 social determinants are specific to countries and have emphasized the need for local studies  
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4 464 that inform local policies and programs.<sup>24 53 54</sup>

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## 7 8 466 **CONCLUSIONS**

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11 467 This is the first study to investigate the association of socioeconomic status with obesity  
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13 468 while considering both the main-effect term of each independent variable and the two-way  
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15 469 interaction- effect terms between independent variables. This study highlights the importance  
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17 470 of interaction effects in studies of the associations of socioeconomic status with obesity.

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20 471 According to the results, moving from models evaluating only main effects to models  
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22 472 evaluating both main and interaction effects may change the association of socioeconomic  
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24 473 status with obesity, the group with the highest likelihood of obesity, the gradient in the  
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26 474 likelihood of obesity by socioeconomic status, and gender differences in the associations of  
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28 475 socioeconomic status with obesity. These results suggest that studies on the association  
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30 476 between socioeconomic status and obesity should include interaction-effect terms for all  
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32 477 characteristics and consider gender differences, and that policy efforts to reduce obesity and  
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34 478 the resulting socioeconomic gradients should be established based on the results of those in-  
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36 479 depth studies. Moreover, further research is needed to examine whether these findings are  
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38 480 valid in other sociocultural settings.  
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## Contributors

WC conceived and designed the study, conducting the literature review and the statistical analysis, writing the paper. JK collected and managed the data. JK, SJL, SL, and RK participated in reviewing the literature and writing the paper.

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## Competing interests

None declared.

## Ethics approval

Institutional Review Board of Yonsei University Graduate School of Public Health.

## Provenance and peer review

Not commissioned; externally peer reviewed.

## Data sharing statement



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4 The data used in this study are available from the Korean Centers for Disease Control and  
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6 Prevention database.  
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For peer review only

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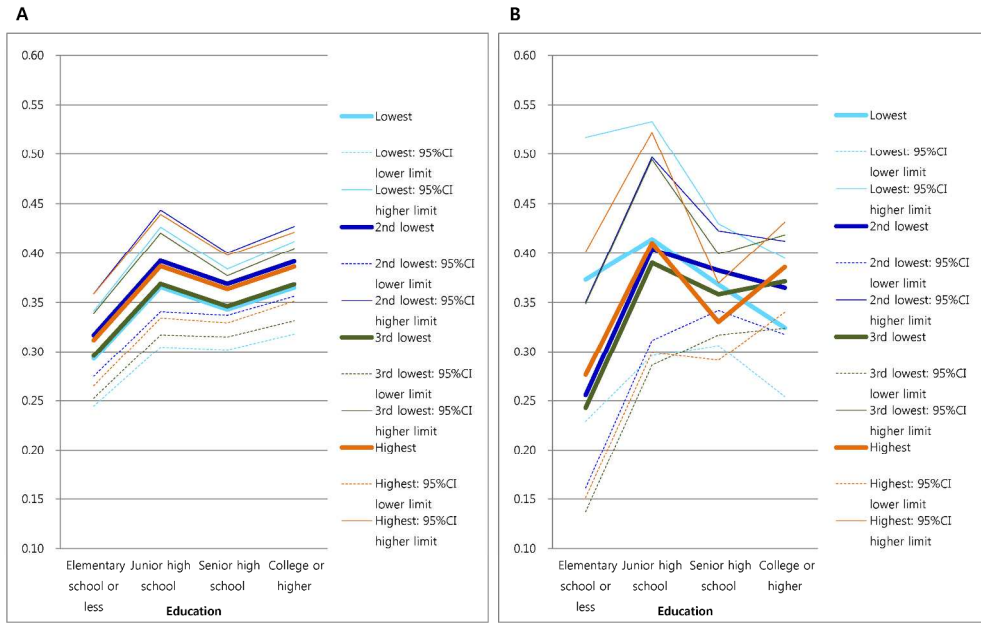


Figure 1 Predicted probabilities of being obese (and their 95% confidence intervals) by education for each income level in men in a model with only main effects (A) and a model with both main and interaction effects (B): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea

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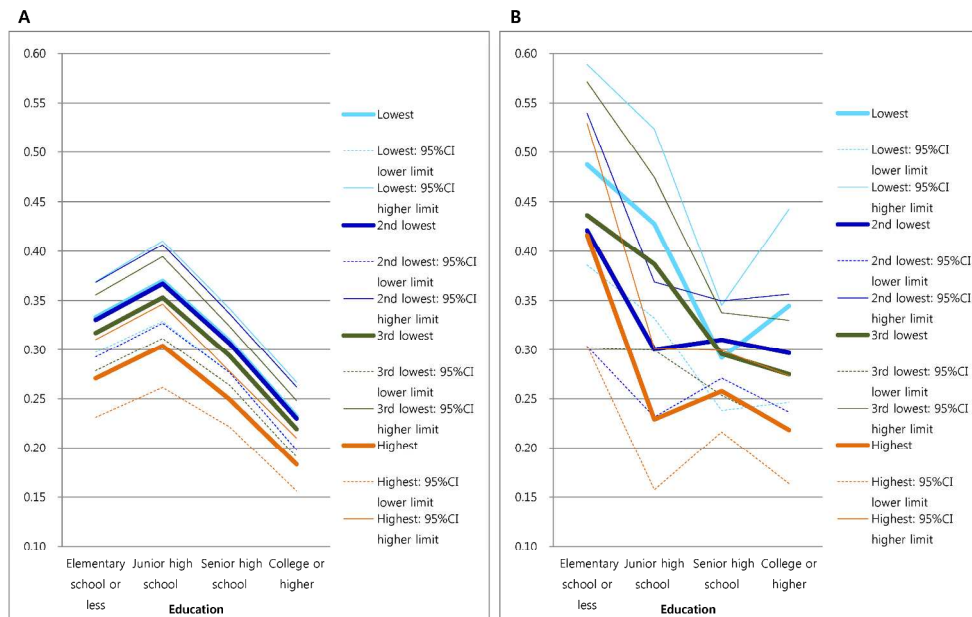


Figure 2 Predicted probabilities of being obese (and their 95% confidence intervals) by education for each income level in women in a model with only main effects (A) and a model with both main and interaction effects (B): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea

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**Table S1** Distribution (%) of sample characteristics in men by education and income (quartiles): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010-2012, South Korea

| Characteristic                   | Overall | Elementary school or less |         |         |      |        | Junior high school |         |         |      |        | Senior high school |         |         |      |        | College or more |         |         |      |        | (Total) |
|----------------------------------|---------|---------------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|-----------------|---------|---------|------|--------|---------|
|                                  |         | Low                       | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low             | 2nd low | 3rd low | High | (Sum)  |         |
| Age, years *                     | 50.8    | 70.5                      | 64.4    | 62.3    | 61.8 | (67.2) | 63.8               | 58.0    | 57.2    | 61.8 | 59.6   | 53.0               | 44.9    | 45.1    | 45.8 | 46.4   | 48.7            | 42.9    | 42.4    | 61.8 | 44.0   |         |
| Marital status                   |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Married                          | 79.7    | 10.6                      | 4.9     | 2.7     | 1.7  | (19.9) | 4.3                | 3.9     | 2.7     | 2.2  | (13.1) | 5.6                | 9.6     | 8.4     | 8.7  | (32.3) | 2.3             | 8.0     | 10.0    | 14.4 | (34.8) | (100.0) |
| Formerly married                 | 4.6     | 22.7                      | 8.9     | 1.8     | 2.1  | (35.4) | 11.2               | 4.1     | 2.1     | 2.4  | (19.8) | 11.5               | 7.1     | 4.7     | 5.5  | (26.8) | 5.3             | 3.8     | 4.1     | 4.7  | (18.0) | (100.0) |
| Never-married                    | 15.7    | 0.5                       | 0.4     | 0.1     | 0.0  | (1.0)  | 1.0                | 0.9     | 0.5     | 0.5  | (2.9)  | 9.7                | 16.2    | 14.0    | 15.8 | (55.7) | 5.7             | 8.3     | 11.7    | 14.8 | (40.5) | (100.0) |
| Residential area                 |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Metro urban                      | 44.2    | 6.1                       | 3.5     | 1.8     | 1.0  | (12.4) | 2.9                | 3.5     | 2.4     | 2.1  | (10.9) | 6.6                | 10.9    | 8.9     | 9.7  | (36.0) | 3.6             | 8.1     | 11.3    | 17.8 | (40.8) | (100.0) |
| Non-metro urban                  | 34.4    | 7.1                       | 3.7     | 1.7     | 1.4  | (14.0) | 4.0                | 3.0     | 2.0     | 1.6  | (10.6) | 6.0                | 10.7    | 10.9    | 10.2 | (37.8) | 2.6             | 9.8     | 11.4    | 14.0 | (37.7) | (100.0) |
| Rural                            | 21.4    | 20.5                      | 7.3     | 4.3     | 2.4  | (34.4) | 6.5                | 4.1     | 2.9     | 2.4  | (15.8) | 7.2                | 9.5     | 6.6     | 8.1  | (31.5) | 2.3             | 4.5     | 5.2     | 6.4  | (18.3) | (100.0) |
| Occupation,                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Unemployed                       | 25.6    | 9.8                       | 6.5     | 3.6     | 2.1  | (22.0) | 4.4                | 5.2     | 3.8     | 3.1  | (16.6) | 6.1                | 13.7    | 10.9    | 11.9 | (42.5) | 1.8             | 5.1     | 5.5     | 6.6  | (18.9) | (100.0) |
| Office worker                    | 26.8    | 0.3                       | 0.1     | 0.3     | 0.3  | (0.9)  | 0.4                | 0.3     | 0.5     | 0.8  | (1.8)  | 1.7                | 6.0     | 6.5     | 7.8  | (22.0) | 3.5             | 14.8    | 21.9    | 35.1 | (75.3) | (100.0) |
| Manual worker                    | 47.6    | 18.7                      | 5.0     | 2.0     | 1.4  | (27.0) | 7.3                | 3.5     | 1.5     | 1.1  | (13.5) | 12.5               | 9.4     | 8.4     | 7.0  | (37.2) | 4.6             | 5.9     | 6.0     | 5.8  | (22.3) | (100.0) |
| Housing status, home owner       | 76.4    | 9.9                       | 4.9     | 2.7     | 1.7  | (19.2) | 3.9                | 3.4     | 2.5     | 2.2  | (12.0) | 5.1                | 9.5     | 9.1     | 10.6 | (34.3) | 2.2             | 7.0     | 10.1    | 15.3 | (34.6) | (100.0) |
| Universal health insurance, NHI  | 98.2    | 9.1                       | 4.4     | 2.3     | 1.4  | (17.2) | 3.9                | 3.4     | 2.4     | 2.0  | (11.7) | 6.3                | 10.6    | 9.2     | 9.7  | (35.8) | 2.8             | 8.0     | 10.2    | 14.3 | (35.3) | (100.0) |
| Private health insurance, holder | 69.2    | 3.2                       | 3.0     | 2.1     | 1.5  | (9.7)  | 2.0                | 3.4     | 2.6     | 2.3  | (10.2) | 4.1                | 11.1    | 10.7    | 12.0 | (37.9) | 2.3             | 9.2     | 12.7    | 18.1 | (42.2) | (100.0) |
| Survey year                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| 2010                             | 35.3    | 9.7                       | 4.4     | 2.2     | 1.4  | (17.6) | 4.4                | 3.1     | 2.5     | 2.3  | (12.3) | 6.3                | 11.7    | 9.2     | 7.8  | (35.0) | 3.4             | 8.3     | 10.9    | 12.4 | (35.1) | (100.0) |
| 2011                             | 34.0    | 9.6                       | 4.2     | 2.1     | 1.6  | (17.5) | 3.7                | 4.2     | 2.2     | 2.0  | (12.0) | 5.9                | 10.0    | 8.9     | 10.8 | (35.6) | 2.5             | 8.2     | 9.0     | 15.2 | (34.8) | (100.0) |

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|                                     |      |      |     |     |     |        |     |     |     |     |        |     |      |      |      |        |     |     |      |      |        |         |
|-------------------------------------|------|------|-----|-----|-----|--------|-----|-----|-----|-----|--------|-----|------|------|------|--------|-----|-----|------|------|--------|---------|
| 2012                                | 30.7 | 9.3  | 4.6 | 2.6 | 1.2 | (17.8) | 4.1 | 3.0 | 2.3 | 1.6 | (11.0) | 7.5 | 9.8  | 9.1  | 20.2 | (36.5) | 2.9 | 7.0 | 10.1 | 14.6 | (34.7) | (100.0) |
| Current smoking status, smoker      | 40.9 | 8.1  | 3.7 | 1.7 | 1.4 | (14.9) | 3.9 | 3.5 | 2.2 | 1.7 | (11.3) | 6.9 | 12.7 | 9.1  | 20.2 | (38.9) | 2.8 | 8.6 | 10.6 | 12.9 | (34.9) | (100.0) |
| Alcohol consumption, excessive      | 32.5 | 3.9  | 2.8 | 1.5 | 0.9 | (9.1)  | 2.2 | 2.7 | 1.4 | 1.8 | (8.0)  | 5.2 | 13.0 | 10.1 | 2.1  | (40.4) | 3.0 | 9.5 | 13.0 | 17.1 | (42.6) | (100.0) |
| Routine physical exercise, inactive | 78.8 | 10.5 | 4.6 | 2.3 | 1.4 | (18.9) | 4.2 | 3.4 | 2.4 | 1.9 | (11.9) | 6.8 | 10.0 | 8.9  | 2.6  | (34.3) | 2.9 | 7.9 | 10.5 | 13.6 | (35.0) | (100.0) |
| Daily sleep duration, short         | 41.5 | 10.1 | 5.0 | 2.3 | 1.4 | (18.8) | 4.1 | 2.8 | 2.0 | 2.2 | (11.2) | 6.4 | 9.2  | 9.4  | 2.9  | (34.0) | 2.8 | 7.4 | 10.2 | 15.6 | (36.1) | (100.0) |
| Daily energy intake, moderate       | 20.1 | 11.2 | 5.1 | 2.0 | 1.7 | (20.0) | 4.6 | 3.4 | 2.2 | 2.3 | (12.5) | 6.4 | 9.8  | 8.8  | 2.0  | (34.0) | 2.6 | 7.6 | 9.9  | 13.5 | (33.5) | (100.0) |
| Self-perceived stress, very high    | 3.4  | 8.4  | 6.0 | 2.8 | 3.2 | (20.4) | 3.2 | 4.8 | 1.6 | 1.2 | (10.8) | 6.8 | 10.4 | 7.2  | 2.8  | (33.2) | 5.2 | 5.2 | 8.0  | 17.2 | (35.6) | (100.0) |
| Self-perceived health, very bad     | 2.4  | 37.6 | 6.7 | 4.5 | 2.3 | (51.1) | 9.6 | 5.6 | 1.7 | 2.8 | (19.7) | 6.7 | 7.3  | 1.7  | 2.6  | (21.4) | 3.9 | 1.7 | 1.1  | 1.1  | (7.9)  | (100.0) |
| Having hypertension                 | 21.4 | 16.9 | 7.1 | 2.9 | 2.2 | (29.1) | 6.9 | 5.0 | 3.4 | 2.4 | (17.7) | 8.9 | 7.6  | 7.6  | 7.4  | (31.5) | 3.1 | 4.6 | 4.8  | 9.1  | (21.6) | (100.0) |
| Having dyslipidemia                 | 6.5  | 9.2  | 5.9 | 3.4 | 1.7 | (20.1) | 6.1 | 5.0 | 3.4 | 2.5 | (17.0) | 8.4 | 7.7  | 7.3  | 2.6  | (33.1) | 2.9 | 6.3 | 6.7  | 14.0 | (29.9) | (100.0) |
| Having diabetes                     | 32.5 | 16.9 | 6.2 | 2.8 | 2.1 | (28.0) | 8.1 | 4.3 | 3.7 | 3.9 | (20.0) | 8.7 | 7.3  | 7.4  | 2.3  | (31.7) | 3.0 | 3.1 | 5.2  | 9.2  | (20.4) | (100.0) |
| Number of participants              |      | 700  | 322 | 167 | 105 | 1294   | 299 | 252 | 171 | 145 | 867    | 479 | 772  | 666  | 700  | 2617   | 216 | 578 | 735  | 1030 | 2559   | 7337    |

N, number; Low, Lowest; High, Highest; NHI, National Health Insurance;  
\*Mean.

**Table S2** Distribution (%) of sample characteristics in women by education and income (quartiles): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010-2012, South Korea

| Characteristic                   | Overall | Elementary school or less |         |         |      |        | Junior high school |         |         |      |        | Senior high school |         |         |      |        | College or more |         |         |      |        | (Total) |
|----------------------------------|---------|---------------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|-----------------|---------|---------|------|--------|---------|
|                                  |         | Low                       | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low             | 2nd low | 3rd low | High | (Sum)  |         |
| Age, years *                     | 50.5    | 69.3                      | 64.2    | 63.4    | 64.9 | (67.0) | 59.6               | 55.4    | 54.9    | 54.6 | (56.2) | 43.7               | 41.4    | 42.9    | 43.0 | (42.6) | 38.5            | 35.9    | 36.2    | 39.1 | (37.5) |         |
| Marital status                   |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Married                          | 69.5    | 13.6                      | 6.8     | 4.0     | 3.0  | (27.3) | 2.6                | 3.6     | 3.1     | 2.8  | (12.1) | 3.6                | 10.5    | 9.3     | 10.5 | (33.9) | 1.2             | 5.9     | 7.8     | 11.8 | (26.7) | (100.0) |
| Formerly married                 | 18.2    | 45.2                      | 12.0    | 6.8     | 6.9  | (71.0) | 3.9                | 2.9     | 1.6     | 1.4  | (9.8)  | 6.3                | 4.2     | 2.1     | 2.2  | (14.9) | 1.3             | 0.9     | 1.1     | 1.0  | (4.3)  | (100.0) |
| Never-married                    | 12.3    | 0.3                       | 0.1     | 0.0     | 0.2  | (0.6)  | 0.5                | 0.3     | 0.2     | 0.1  | (1.1)  | 8.7                | 12.0    | 9.4     | 13.6 | (43.7) | 3.9             | 12.7    | 15.8    | 22.3 | (54.7) | (100.0) |
| Residential area                 |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Metro urban                      | 44.5    | 12.2                      | 5.8     | 3.6     | 2.6  | (24.3) | 2.5                | 3.0     | 2.4     | 2.4  | (10.3) | 5.3                | 9.9     | 8.0     | 10.9 | (34.1) | 1.7             | 6.5     | 8.8     | 14.2 | (31.3) | (100.0) |
| Non-metro urban                  | 35.0    | 13.9                      | 6.3     | 3.7     | 3.0  | (26.8) | 2.8                | 2.9     | 2.5     | 2.2  | (10.4) | 4.9                | 10.9    | 9.6     | 9.6  | (35.0) | 1.8             | 6.4     | 8.6     | 11.0 | (27.8) | (100.0) |
| Rural                            | 20.5    | 36.3                      | 10.2    | 5.5     | 5.4  | (57.4) | 2.5                | 3.5     | 2.5     | 1.8  | (10.3) | 3.4                | 6.5     | 5.1     | 5.7  | (20.7) | 0.7             | 3.5     | 3.0     | 4.4  | (11.6) | (100.0) |
| Occupation,                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Unemployed                       | 52.6    | 20.8                      | 9.5     | 5.5     | 5.0  | (40.8) | 2.9                | 4.8     | 4.5     | 4.1  | (16.2) | 5.0                | 10.8    | 8.9     | 9.2  | (33.9) | 0.8             | 2.5     | 2.3     | 3.6  | (9.2)  | (100.0) |
| Office worker                    | 16.0    | 0.4                       | 0.3     | 0.1     | 0.2  | (1.0)  | 0.4                | 0.9     | 0.2     | 0.5  | (2.0)  | 2.6                | 7.0     | 8.3     | 10.5 | (28.4) | 2.4             | 11.8    | 21.1    | 33.4 | (68.6) | (100.0) |
| Manual worker                    | 31.4    | 21.2                      | 7.3     | 4.3     | 3.3  | (36.2) | 3.1                | 2.7     | 2.0     | 1.6  | (9.3)  | 5.3                | 9.6     | 7.3     | 9.1  | (31.3) | 1.8             | 6.1     | 6.6     | 8.8  | (23.2) | (100.0) |
| Housing status, home owner       | 73.5    | 16.0                      | 7.8     | 4.7     | 4.0  | (32.5) | 2.3                | 3.1     | 2.9     | 2.6  | (10.8) | 3.2                | 8.5     | 8.3     | 10.8 | (30.8) | 1.2             | 5.2     | 7.3     | 12.2 | (25.9) | (100.0) |
| Universal health insurance, NHI  | 97.0    | 16.6                      | 7.0     | 4.1     | 3.4  | (31.1) | 2.5                | 3.1     | 2.5     | 2.3  | (10.4) | 4.3                | 9.7     | 8.2     | 9.6  | (31.8) | 1.6             | 6.0     | 7.8     | 11.4 | (26.7) | (100.0) |
| Private health insurance, holder | 70.7    | 7.7                       | 5.2     | 3.4     | 2.9  | (19.2) | 1.9                | 3.3     | 2.8     | 2.8  | (10.7) | 4.3                | 11.1    | 9.9     | 12.1 | (37.5) | 1.6             | 7.1     | 9.6     | 14.4 | (32.6) | (100.0) |
| Survey year                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| 2010                             | 34.0    | 17.1                      | 7.3     | 4.3     | 3.4  | (32.0) | 2.4                | 2.8     | 2.4     | 2.3  | (9.9)  | 4.9                | 10.5    | 7.9     | 8.2  | (31.5) | 1.6             | 6.0     | 8.2     | 10.8 | (26.6) | (100.0) |
| 2011                             | 34.1    | 18.1                      | 7.1     | 3.6     | 3.4  | (32.2) | 2.4                | 3.5     | 2.4     | 2.3  | (10.6) | 4.3                | 8.6     | 8.1     | 10.6 | (31.6) | 1.4             | 5.7     | 7.2     | 11.4 | (25.7) | (100.0) |

|                                     |      |      |      |     |     |        |     |     |     |     |        |      |      |      |      |        |     |     |      |      |        |         |
|-------------------------------------|------|------|------|-----|-----|--------|-----|-----|-----|-----|--------|------|------|------|------|--------|-----|-----|------|------|--------|---------|
| 2012                                | 31.9 | 18.1 | 6.2  | 4.1 | 3.2 | (31.7) | 3.0 | 2.9 | 2.6 | 2.1 | (10.5) | 5.2  | 9.5  | 7.9  | 9.3  | (31.9) | 1.7 | 5.9 | 7.2  | 11.1 | (25.9) | (100.0) |
| Current smoking status, smoker      | 5.5  | 14.8 | 5.8  | 2.0 | 1.6 | (24.2) | 3.6 | 5.3 | 2.0 | 1.1 | (12.0) | 11.5 | 15.5 | 9.3  | 6.9  | (43.2) | 1.5 | 4.4 | 6.6  | 8.2  | (20.6) | (100.0) |
| Alcohol consumption, excessive      | 12.3 | 4.0  | 2.9  | 1.3 | 1.6 | (9.8)  | 2.3 | 2.3 | 1.3 | 1.8 | (7.7)  | 8.9  | 13.3 | 12.2 | 13.5 | (47.9) | 1.8 | 7.7 | 11.1 | 14.0 | (34.5) | (100.0) |
| Routine physical exercise, inactive | 83.6 | 18.4 | 7.0  | 3.9 | 3.3 | (32.5) | 2.5 | 3.1 | 2.4 | 2.0 | (10.0) | 4.9  | 9.5  | 7.8  | 8.7  | (30.9) | 1.6 | 6.1 | 7.9  | 11.1 | (26.7) | (100.0) |
| Daily sleep duration, short         | 42.3 | 22.9 | 8.1  | 5.3 | 4.1 | (40.5) | 3.1 | 3.6 | 2.4 | 2.2 | (11.3) | 4.6  | 8.5  | 6.5  | 8.5  | (28.1) | 1.0 | 4.1 | 5.6  | 9.5  | (20.1) | (100.0) |
| Daily energy intake, moderate       | 16.2 | 15.4 | 7.2  | 4.3 | 3.4 | (30.3) | 2.4 | 3.1 | 3.0 | 2.1 | (10.7) | 5.2  | 11.2 | 8.6  | 9.4  | (34.5) | 1.4 | 6.1 | 7.3  | 9.8  | (24.5) | (100.0) |
| Self-perceived stress, very high    | 4.9  | 19.7 | 9.7  | 4.1 | 3.5 | (37.0) | 3.9 | 1.9 | 2.3 | 1.6 | (9.7)  | 6.0  | 9.2  | 8.6  | 6.6  | (30.4) | 2.3 | 4.7 | 6.4  | 9.7  | (23.0) | (100.0) |
| Self-perceived health, very bad     | 4.5  | 49.9 | 15.4 | 5.9 | 4.3 | (75.5) | 3.9 | 1.8 | 2.0 | 2.0 | (9.7)  | 3.0  | 2.7  | 2.7  | 2.3  | (10.7) | 0.9 | 1.4 | 0.2  | 1.6  | (4.1)  | (100.0) |
| Having hypertension                 | 22.2 | 40.9 | 13.2 | 7.6 | 6.4 | (68.1) | 4.0 | 3.5 | 3.1 | 2.4 | (13.0) | 3.1  | 4.5  | 3.5  | 4.0  | (15.1) | 0.4 | 0.7 | 1.1  | 1.6  | (3.9)  | (100.0) |
| Having dyslipidemia                 | 8.5  | 30.6 | 12.0 | 7.4 | 5.5 | (55.4) | 5.1 | 4.6 | 3.4 | 2.7 | (15.9) | 3.3  | 5.8  | 5.3  | 7.4  | (21.8) | 0.6 | 1.0 | 1.8  | 3.6  | (6.9)  | (100.0) |
| Having diabetes                     | 7.0  | 43.0 | 14.1 | 7.1 | 5.5 | (69.7) | 5.1 | 3.5 | 2.3 | 1.6 | (12.5) | 2.6  | 5.1  | 3.5  | 2.6  | (13.8) | 0.3 | 1.0 | 1.2  | 1.6  | (4.1)  | (100.0) |
| Number of participants              |      | 1758 | 683  | 397 | 330 | 3168   | 257 | 304 | 244 | 219 | 1024   | 471  | 947  | 790  | 928  | 3136   | 155 | 580 | 746  | 1099 | 2580   | 9908    |

N, number; Low, Lowest; High, Highest; NHI, National Health Insurance; Mean.

## STROBE Statement—checklist of items that should be included in reports of observational studies

|                              | Item No | Recommendation  |
|------------------------------|---------|---|
| <b>Title and abstract</b>    | 1       | <p>(a) Indicate the study's design with a commonly used term in the title or the abstract<br/>→ We indicated it in the title and the abstract (page 1 and 3).</p> <p>(b) Provide in the abstract an informative and balanced summary of what was done and what was found<br/>→ We provided them in the abstract (pages 3-4).</p>  |
| <b>Introduction</b>          |         |   |
| Background/rationale         | 2       | <p>Explain the scientific background and rationale for the investigation being reported<br/>→ We explained them in the introduction (pages 6-7).</p>  |
| Objectives                   | 3       | <p>State specific objectives, including any prespecified hypotheses<br/>→ We stated them in the introduction (pages 6-7)</p>  |
| <b>Methods</b>               |         |   |
| Study design                 | 4       | <p>Present key elements of study design early in the paper<br/>→ We presented them in the measures and variables section of the materials and methods (pages 8-9).</p>  |
| Setting                      | 5       | <p>Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection<br/>→ We described them in the data source and study sample sections of the materials and methods (pages 7-8).</p>   |
| Participants                 | 6       | <p>(a) <i>Cohort study</i>—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up<br/><i>Case-control study</i>—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls<br/><b><i>Cross-sectional study</i></b>—Give the eligibility criteria, and the sources and methods of selection of participants<br/>→ We presented them in the data source and study sample sections of the materials and methods (pages 7-8).</p> <p>(b) <i>Cohort study</i>—For matched studies, give matching criteria and number of exposed and unexposed<br/><i>Case-control study</i>—For matched studies, give matching criteria and the number of controls per case<br/>→ N/A</p> |
| Variables                    | 7       | <p>Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable<br/>→ We clearly defined them in the measures and variables section of the materials and methods (pages 8-9).</p>   |
| Data sources/<br>measurement | 8*      | <p>For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group.<br/>→ We indicated them in the materials and methods (pages 7-11).</p>   |
| Bias                         | 9       | <p>Describe any efforts to address potential sources of bias</p>  |

|                        |     |   |
|------------------------|-----|---|
|                        |     | → We described them in the strengths and limitations section of the discussion (page 29).   |
| Study size             | 10  | Explain how the study size was arrived at<br>→ We explained the study size in the data source and study sample section of the materials and methods (pages 7-8).  |
| Quantitative variables | 11  | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why<br>→ We explained quantitative variables' handling in the measures and variables section of the materials and methods (pages 8-9).   |
| Statistical methods    | 12  | (a) Describe all statistical methods, including those used to control for confounding<br>→ We described statistical methods in the analytic procedures section of the materials and methods (pages 9-11).<br>(b) Describe any methods used to examine subgroups and interactions<br>→ We described statistical methods in the analytic procedures section of the materials and methods (pages 9-11).<br>(c) Explain how missing data were addressed<br>→ N/A<br>(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed<br><i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed<br><b><i>Cross-sectional study</i></b> —If applicable, describe analytical methods taking account of sampling strategy<br>→ We described them in the analytic procedures section of the materials and methods (pages 9-11).<br>(e) Describe any sensitivity analyses<br>→ N/A |
| <b>Results</b>         |     |   |
| Participants           | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed<br>→ We reported them in the data source and study sample section of the materials and methods and in the table (pages 7-8, 12-15).<br>(b) Give reasons for non-participation at each stage<br>→ N/A<br>(c) Consider use of a flow diagram<br>→ N/A   |
| Descriptive data       | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders<br>→ We described them in the data source and study sample section of the materials and methods and in the table (pages 7-8, 12-15).<br>(b) Indicate number of participants with missing data for each variable of interest<br>→ N/A<br>(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)<br>→ N/A  |
| Outcome data           | 15* | <i>Cohort study</i> —Report numbers of outcome events or summary measures over time<br><i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure   |

|                          |    |  |
|--------------------------|----|--|
|                          |    | <b><u>Cross-sectional study</u></b> —Report numbers of outcome events or summary measures<br>→ We reported them in the table (pages 12-15; Table 1).   |
| Main results             | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included<br>→ We indicated them in the results and the table (pages 16-22, Table 2)  |
|                          |    | (b) Report category boundaries when continuous variables were categorized<br>→ We reported them in the measures and variables section of the materials and methods (pages 8-9).  |
|                          |    | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period<br>→ N/A  |
| Other analyses           | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses<br>→ N/A  |
| <b>Discussion</b>        |    |  |
| Key results              | 18 | Summarise key results with reference to study objectives<br>→ We indicated them in the comparison to previous studies section of the discussion (pages 22-23).   |
| Limitations              | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias<br>→ We discussed them in the strengths and limitations section of the discussion (page 29).                                  |
| Interpretation           | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence<br>→ We discussed them in the discussion (pages 22-30).   |
| Generalisability         | 21 | Discuss the generalisability (external validity) of the study results<br>→ We discussed it in the public health implications section of the discussion and in the conclusion (pages 29-30).  |
| <b>Other information</b> |    |  |
| Funding                  | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based<br>→ This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. |

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).



# BMJ Open

## Gender-specific interactions between education and income in relation to obesity: a cross-sectional analysis of the Fifth Korean National Health and Nutrition Examination Survey (KNHANES V)

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|                                 |   |

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4 **Gender-specific interactions between education and income in**  
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6 **relation to obesity: a cross-sectional analysis of the Fifth Korean**  
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8 **National Health and Nutrition Examination Survey (KNHANES V)**  
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## 1 **ABSTRACT**

### 3 **Objectives**

4 To identify gender-specific associations between education and income in relation to obesity  
5 in developed countries by considering both the interaction-effect terms of the independent  
6 variables and their main-effect terms.

### 7 **Design**

8 A cross-sectional study. Education and income levels were chosen as socioeconomic status  
9 indicators. Socio-demographics, lifestyles and medical conditions were used as covariates in  
10 multivariable logistic regression models. Adjusted odds ratios and predicted probabilities of  
11 being obese were computed and adjusted for a complex survey design.

### 12 **Setting**

13 Data were obtained from the Fifth Korea National Health and Nutrition Examination Survey  
14 (2010-2012).

### 15 **Participants**

16 The sample included 7,337 male and 9,908 female participants aged 19 years or older.

### 17 **Outcome measure**

18 Obesity was defined as body mass index of 25 or more, according to a guideline for Asians.

### 19 **Results**

20 In models with no interaction-effect terms of independent variables, education was  
21 significantly associated with obesity in both men and women, but income was significant  
22 only in women. However, in models with the interaction-effect terms, education was  
23 significant only in women, but income was significant only in men. The interaction effect

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4 24 between income and education was significant in men but not in women. Participants having  
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6 25 the highest predicted probability of being obese over educational and income levels differed  
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8 26 between the two types of models, and between men and women. A prediction using the  
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10 27 models with the interaction-effect terms demonstrated that for all men, the highest level of  
11  
12 28 formal education was associated with an increase in their probability of being obese by as  
13  
14 29 much as 26%.

### 30 **Conclusions**

31 The well-known, negative association between socioeconomic status and obesity in  
32 developed countries may not be valid when interaction effects are included. Ignoring these  
33 effects and their gender differences may result in the targeting of wrong populations for  
34 reducing obesity prevalence and its resultant socioeconomic gradients.

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4 35 **Article summary**  
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7 36 **Strengths and limitations of this study**  
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- 9 37 1. The study included a nationally representative sample of South Korean adults.  
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11 38 2. The study is the first to investigate the associations of education and income with  
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13 39 obesity while considering both the main-effect terms of all independent variables and  
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15 40 their interaction-effect terms.  
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18 41 3. The study compared the predicted probabilities of being obese among various sets of  
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20 42 education and income levels for each gender.  
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22 43 4. The causal inferences could not be examined due to the cross-sectional design.  
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## 1 INTRODUCTION

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3 Numerous studies have investigated various factors related to obesity, and have identified the  
4 relationship between socioeconomic status and obesity.<sup>1-3</sup> Despite strong inconsistencies  
5 regarding the relationship between socioeconomic status and obesity either in a gender or  
6 between genders, most literature indicated that in developed countries, socioeconomic status  
7 is negatively correlated with obesity in both men and women, being more consistent in  
8 women than in men.<sup>1 2 4-7</sup> However, because empirical studies of obesity have often ignored  
9 the interaction effects among various characteristics, these studies have failed to detect  
10 complex associations between different levels of socioeconomic status in relation to obesity;  
11 moreover, they have failed to explain differences among different population groups  
12 regarding the mechanisms through which socioeconomic status becomes associated with  
13 obesity.

14 To put it concretely, when the interaction effects among various characteristics are  
15 considered, previous studies have not answered the question as to whether the above-  
16 mentioned, well-known associations between socioeconomic status and obesity remain valid  
17 in developed countries. Moreover, they have seldom explored why a socioeconomic status  
18 indicator sometimes interacts with another socioeconomic status indicator with regard to  
19 obesity, and whether the interaction differs by gender; whether the likelihood of being obese  
20 with regard to some levels of socioeconomic status remains the same before and after  
21 consideration of the interaction effects; and whether government can reduce the prevalence of  
22 obesity and change the socioeconomic gradient in the prevalence of this condition by  
23 providing all individuals with the highest level of socioeconomic status possible.

24 Attempting to fill the gap between previous findings and the unanswered questions,

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4 25 this study chose education and income levels as socioeconomic status indicators because they  
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6 26 complement each other: educational level is established in early adulthood and tends to  
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8 27 remain unchanged later in life, while income level may change throughout adult life. In  
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10 28 particular, this study used data from South Korea, which has industrialized rapidly and is now  
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12 29 categorized as one of the ten largest advanced economies in the world.<sup>8</sup> Nevertheless, South  
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14 30 Korea is still noted for pronounced gender inequality almost everywhere, especially in the  
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16 31 labor markets.<sup>9 10</sup>

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19 32 This study considered two models for each gender: one included only the main-  
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21 33 effect terms of all independent variables, and the other included the two-way interaction-  
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23 34 effect terms between the independent variables, as well as their main-effect terms.  
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25 35 Considering the complex survey design, this study used multivariable logistic regression  
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27 36 analyses to compute the odds ratios of obesity and to predict the probability that a man or  
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29 37 woman would be obese if he or she had a particular set of education and income levels.  
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## 34 35 39 **MATERIALS AND METHODS**

### 36 37 40 **Data source and study sample**

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39 41 This study was based on the Fifth Korea National Health and Nutrition Examination Survey  
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41 42 (KNHANES V), 2010–2012, which used a stratified multistage clustered probability  
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43 43 sampling design to collect data on the non-institutionalized, civilian population of South  
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45 44 Korea on behalf of the Korean Centers for Disease Control and Prevention.<sup>11</sup> This survey was  
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47 45 composed of a health interview and a nutrition survey conducted at the participants' homes,  
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49 46 as well a physical examination conducted by physicians at designated examination centers.  
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4 47 Detailed information about the survey design and characteristics is available at the  
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6 48 KNHANES website.<sup>11</sup>  
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9 49 From KNHANES V, this study accessed data from a pool of 25,534 individuals  
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11 50 (8,958 in 2010, 8,518 in 2011, and 8,058 in 2012). Of this group, 24,173 had participated in  
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13 51 the interviews, and 18,571 individuals aged 19 years or older underwent physical  
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15 52 examinations. A total of 17,245 (92.86%) participants (7,337 men, 9,908 women) were  
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17 53 included in this study because they had the required information in their files. The ethical  
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19 54 review board of the educational institution where the research was conducted approved this  
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21 55 study.  
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## 24 56

### 25 57 **Measures and variables**

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28 58 The obesity status of each participant was determined anthropometrically using data from the  
29  
30 59 physical examination. Height was measured using a portable stadiometer, and body weight  
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32 60 was measured using a calibrated balance-beam scale, and the body mass index (BMI) was  
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34 61 calculated from these height and weight measurements. According to the guidelines proposed  
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36 62 by the World Health Organization indicating that Asians have a lower average BMI,<sup>12</sup> this  
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38 63 study defined general obesity as a BMI of at least 25. Also, because the percentage of  
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40 64 participants with BMI of less than 18.5 in the sample was very small (4.5%, 781 participants),  
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42 65 we combined participants with BMI of less than 18.5 and those with BMI between 18.5 to 25  
43  
44 66 into a single group. Therefore, a dichotomous outcome variable was constructed with a value  
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46 67 of 1 (obesity, BMI of 25 or higher) and 0 (non-obesity, BMI of less than 25).<sup>13-15</sup>  
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49 68 Levels of education and income were chosen as socioeconomic status indicators.

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52 69 Education was defined as the highest level of formal education completed as of the date of  
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4 70 the interview. This study categorized education into four levels: elementary school or less,  
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6 71 junior high school, senior high school, and college or more. For income, this study used an  
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8 72 equivalized monthly household income calculation ([monthly overall household income]  
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10 73 [household size]<sup>-0.5</sup>) and divided the participants into four quartiles.

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13 74 Nine sociodemographic characteristics, including gender, were incorporated as  
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15 75 covariates. Age was treated as a continuous variable, and marital status was categorized into  
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17 76 married, formerly married, and never married. Residential area was divided into metropolitan  
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19 77 urban area, non-metropolitan urban area, and rural area. Occupation was grouped into  
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21 78 unemployed, office worker, and manual worker. Housing status was coded in terms of  
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23 79 whether a participant was a renter or a home owner. Participants were categorized according  
24  
25 80 to whether they were enrolled in National Health Insurance or Medical Care Aid for regular  
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27 81 or low-income individuals, respectively, with regard to the universal health insurance  
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29 82 program. Participants with private health insurance were also noted. Survey year was added  
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31 83 to control for any fixed time effect.

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35 84 This study also incorporated ten characteristics about lifestyle and medical conditions.  
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37 85 Participants were grouped in terms of the following categories: 1) smoking, 2) excessive  
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39 86 alcohol consumption (at high risk due to drinking according to the gender-specific guidelines  
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41 87 of the World Health Organization),<sup>16</sup> 3) routinely exercising (physical activity as defined as  
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43 88 the participation in moderate or vigorous exercise for a respective frequency and duration),<sup>17</sup>  
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45 89 4) daily sleep duration (sleeping less than 7 h per day was defined as sleeping for a short  
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47 90 duration),<sup>18</sup> 5) daily energy intake (moderate energy intake was defined as total energy intake  
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49 91 within 1.25× of participants' estimated daily energy requirement),<sup>19</sup> 6) self-perceived stress, 7)  
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51 92 self-perceived health, 8) hypertension, 9) dyslipidemia, and 10) diabetes. The presence of the  
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53 93 last three chronic diseases was determined by a prior physician diagnosis at the pre-surgery

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### 96 **Analytic procedures**

97 A six-fold analysis was performed. First, this study tested differences in the distributions of  
98 variables among men and women using the *t*-test for continuous variables and the  $\chi^2$  test for  
99 categorical variables. Second, this study tested the association of each variable with obesity  
100 by gender using the  $\chi^2$  test. Third, gender interaction effects were examined, for which simple  
101 logistic regression models were constructed with main effects for gender and the variable of  
102 interest as well as the interaction effects of the two variables. Due to the results, the  
103 remaining analyses were stratified by gender.

104 Fourth, to fit the multivariable logistic regression models, this study continued to re-  
105 categorize each of the variables and defined each variable's reference category differently  
106 until no strong multicollinearity was found for the main-effect models and no evidence of a  
107 lack of goodness-of-fit was found in each model. The reference groups for each categorical  
108 variable analyzed were: married for marital status, metro urban for residential area,  
109 elementary school or less for education, the lowest quartile for income, manual workers for  
110 occupation, home owner for housing status, National Health Insurance for universal health  
111 insurance, non-holder for private health insurance, year 2010 for survey year, non-smoker for  
112 current smoking status, not excessive for alcohol consumption, physically active for routine  
113 physical exercise, non-short for daily sleep duration, not moderate for daily energy intake, not  
114 very high for self-perceived stress, not very bad for self-perceived health, no for hypertension,  
115 no for dyslipidemia, and no for diabetes. Therefore, the values for the variance inflation  
116 factor became less than 3.65, and p-values based on the Hosmer-Lemeshow statistic became  
117 higher than 0.26.

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4 118 Fifth, this study estimated the adjusted odds ratios (ORs) of obesity and their 95%  
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6 119 confidence intervals (CIs) after fully adjusting for covariates. Two models were considered  
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8 120 for each gender: Model 1 included only the main-effect term of every variable, and Model 2  
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10 121 included the main-effect terms for each variable as well the two-way interaction-effect terms  
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12 122 between the variables. For the two-way interaction-effect terms between the variables, we  
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14 123 included interaction-effect terms between each pair of independent variables including  
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16 124 income, education, and 9 socio-demographic covariates. We considered not only the  
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18 125 interaction-effect terms between education and income, but also the interaction-effect terms  
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20 126 of each of the other independent variables. In order to identify a purer interaction-effect  
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22 127 between education and income in relation to obesity, we needed to control for other possible  
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24 128 variables that could influence obesity including 1) main effects of each independent variable,  
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26 129 2) interaction-effect terms between education and each of the 9 socio-demographic covariates,  
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28 130 3) interaction-effect terms between income and each of the 9 socio-demographic covariates,  
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30 131 and 4) interaction-effect terms between each two of all 9 socio-demographic covariates. In  
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32 132 addition, the reasons why we considered the two-way interaction-effect terms between the  
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34 133 variables, rather than the three-way or greater interaction-effect terms, were: (1) as we  
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36 134 included three-way or greater interaction-effect terms, we had more difficulty having a  
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38 135 sufficient number of observations for the analyses in combined categories of independent  
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40 136 variables associated with the interactions, and (2) two-way interactions were sufficient to  
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42 137 emphasize the importance of gender-specific interactions between education and income in  
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44 138 relation to obesity.

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49 139 Finally, to assess the association of each level of a socioeconomic status indicator  
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51 140 with obesity and to compare these associations across categories for both socioeconomic  
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53 141 status indicators, this study predicted the probability of a participant being obese (and its 95%  
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4 142 confidence intervals) if he or she had a particular set of education and income levels. These  
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6 143 probabilities, which were calculated by gender, denote the average of all participants'  
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8 144 probabilities if each participant belonged to a particular set of education and income levels,  
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10 145 while maintaining participant characteristics for the other variables constant.  
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13 146 All analyses and tests were conducted considering the sampling design of the survey.  
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15 147 However, for convenience, the descriptive statistics are shown as unweighted. P-values <  
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17 148 0.05 were considered statistically significance. The SAS 9.2 software (SAS Institute, Cary,  
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19 149 NC, USA) and STATA 12 software (StataCorp, College Station, TX, USA) were used to  
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21 150 perform all statistical analyses.  
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## 25 26 152 **RESULTS**

### 27 28 29 153 **Descriptive statistics**

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31 154 The rate of obesity was significantly higher in men (34.96%) than in women (29.67%), as  
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33 155 indicated by the significantly higher BMI in men than in women (Table 1). All characteristics  
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35 156 differed significantly by gender except for residential area, housing status, enrollment in a  
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37 157 private health insurance plan, survey year, daily sleep duration, and diabetes status.  
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**Table 1** Sample characteristics and their associations with obesity by gender: the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010-2012, South Korea

|                                       | Distribution, N (%) |              |          | Obesity, % |         |          |
|---------------------------------------|---------------------|--------------|----------|------------|---------|----------|
|                                       | Men                 | Women        | p Value† | Men        | Women   | p Value‡ |
| Body mass index, kg m <sup>-2</sup> * | 23.97 (3.1)         | 23.43 (3.6)  | <0.001   |            |         |          |
| Obesity                               | 2565 (35.0)         | 2940 (29.7)  | <0.001   |            |         |          |
| Age, years*                           | 50.79 (16.4)        | 50.48 (16.6) | <0.001   | 35.1‡      | 34.7‡   | <0.001   |
| Marital status                        |                     |              | <0.001   | <0.001§    | <0.001§ | <0.001   |
| Married                               | 5848 (79.7)         | 6887 (69.5)  |          | 36.0       | 30.5    |          |
| Formerly married                      | 339 (4.6)           | 1803 (18.2)  |          | 30.1       | 37.4    |          |
| Never-married                         | 1150 (15.7)         | 1218 (12.3)  |          | 31.0       | 13.4    |          |
| Residential area                      |                     |              | 0.446    | 0.259§     | <0.001§ | <0.001   |
| Metro urban                           | 3240 (44.2)         | 4404 (44.5)  |          | 35.2       | 27.0    |          |
| Non-metro urban                       | 2523 (34.4)         | 3471 (35.0)  |          | 36.6       | 29.2    |          |
| Rural                                 | 1574 (21.4)         | 2033 (20.5)  |          | 31.9       | 36.4    |          |
| Education                             |                     |              | <0.001   | <0.001§    | <0.001§ | <0.001   |
| Elementary school or less             | 1294 (17.6)         | 3168 (32.0)  |          | 26.6       | 40.2    |          |
| Junior high school                    | 867 (11.8)          | 1024 (10.3)  |          | 36.1       | 38.6    |          |
| Senior high school                    | 2617 (35.7)         | 3136 (31.7)  |          | 34.5       | 27.1    |          |
| College or more                       | 2559 (34.9)         | 2580 (26.0)  |          | 39.3       | 16.4    |          |
| Income, quartiles                     |                     |              | <0.001   | 0.002§     | <0.001§ | <0.001   |
| Lowest                                | 1694 (23.1)         | 2641 (26.6)  |          | 28.4       | 36.8    |          |
| 2nd lowest                            | 1924 (26.2)         | 2514 (25.4)  |          | 36.5       | 31.7    |          |
| 3rd lowest                            | 1739 (23.7)         | 2177 (22.0)  |          | 34.9       | 28.0    |          |
| Highest                               | 1980 (27.0)         | 2576 (26.0)  |          | 39.1       | 21.8    |          |
| Occupation                            |                     |              | <0.001   | <0.001§    | <0.001§ | <0.001   |
| Unemployed                            | 1878 (25.6)         | 5208 (52.6)  |          | 28.7       | 31.1    |          |
| Office worker                         | 1965 (26.8)         | 1586 (16.0)  |          | 42.1       | 17.5    |          |
| Manual worker                         | 3494 (47.6)         | 3114 (31.4)  |          | 34.3       | 33.6    |          |

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| 3  |                            |             |             |        |         |         |        |
| 4  |                            |             |             |        |         |         |        |
| 5  | Housing status             |             |             | 0.158  | 0.945§  | 0.843§  | 0.838  |
| 6  | Home owner                 | 5606 (76.4) | 7280 (73.5) |        | 35.1    | 29.5    |        |
| 7  | Renter                     | 1731 (23.6) | 2628 (26.5) |        | 34.6    | 30.1    |        |
| 8  | Universal health insurance |             |             | <0.001 | 0.020§  | 0.004§  | <0.001 |
| 9  | National Health Insurance  | 7204 (98.2) | 9609 (97.0) |        | 35.2    | 29.4    |        |
| 10 | Medical Care Aid           | 133 (1.8)   | 299 (3.0)   |        | 24.8    | 39.8    |        |
| 11 | Private health insurance   |             |             | 0.181  | <0.001§ | <0.001§ | <0.001 |
| 12 | Non-holder                 | 2258 (30.8) | 2898 (29.3) |        | 29.3    | 34.9    |        |
| 13 | Holder                     | 5079 (69.2) | 7010 (70.7) |        | 37.5    | 27.5    |        |
| 14 | Survey year                |             |             | 0.831  | 0.695§  | 0.133§  | 0.162  |
| 15 | 2010                       | 2592 (35.3) | 3364 (34.0) |        | 35.2    | 28.3    |        |
| 16 | 2011                       | 2494 (34.0) | 3380 (34.1) |        | 34.6    | 30.4    |        |
| 17 | 2012                       | 2251 (30.7) | 3164 (31.9) |        | 35.1    | 30.4    |        |
| 18 | Current smoking status     |             |             | <0.001 | 0.375§  | 0.936§  | 0.729  |
| 19 | Non-smoker                 | 4336 (59.1) | 9359 (94.5) |        | 36.1    | 29.8    |        |
| 20 | Smoker                     | 3001 (40.9) | 549 (5.5)   |        | 33.3    | 27.1    |        |
| 21 | Alcohol consumption        |             |             | <0.001 | <0.001§ | 0.064§  | <0.001 |
| 22 | Not excessive              | 4950 (67.5) | 8689 (87.7) |        | 31.5    | 30.1    |        |
| 23 | Excessive                  | 2387 (32.5) | 1219 (12.3) |        | 42.1    | 26.7    |        |
| 24 | Routine physical exercise  |             |             | <0.001 | 0.838§  | <0.001§ | 0.012  |
| 25 | Physically active          | 1552 (21.2) | 1620 (16.4) |        | 35.6    | 32.8    |        |
| 26 | Physically inactive        | 5785 (78.8) | 8288 (83.6) |        | 34.8    | 29.1    |        |
| 27 | Daily sleep duration       |             |             | 0.992  | 0.150§  | <0.001§ | 0.007  |
| 28 | Non-short                  | 4291 (58.5) | 5717 (57.7) |        | 34.2    | 27.4    |        |
| 29 | Short                      | 3046 (41.5) | 4191 (42.3) |        | 36.0    | 32.8    |        |
| 30 | Daily energy intake        |             |             | <0.001 | 0.818§  | <0.001§ | <0.001 |
| 31 | Not moderate               | 5859 (79.9) | 8306 (83.8) |        | 34.9    | 28.0    |        |
| 32 | Moderate                   | 1478 (20.1) | 1602 (16.2) |        | 35.4    | 38.5    |        |
| 33 | Self-perceived stress      |             |             | <0.001 | 0.969§  | 0.031§  | 0.236  |
| 34 | Not very high              | 7087 (96.6) | 9421 (95.1) |        | 35.1    | 29.5    |        |

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|------------------------|-------------|-------------|--------|---------|---------|--------|
| Very high              | 250 (3.4)   | 487 (4.9)   |        | 32.4    | 33.3    |        |
| Self-perceived health  |             |             | <0.001 | 0.362§  | <0.001§ | 0.002  |
| Not very bad           | 7159 (97.6) | 9467 (95.5) |        | 35.2    | 29.1    |        |
| Very bad               | 178 (2.4)   | 441 (4.5)   |        | 24.2    | 42.4    |        |
| Hypertension           |             |             | <0.001 | <0.001§ | <0.001§ | <0.001 |
| No                     | 5764 (78.6) | 7713 (77.8) |        | 32.6    | 24.3    |        |
| Yes                    | 1573 (21.4) | 2195 (22.2) |        | 43.6    | 48.5    |        |
| Dyslipidemia           |             |             | <0.001 | <0.001§ | <0.001§ | 0.137  |
| No                     | 6859 (93.5) | 9065 (91.5) |        | 33.9    | 27.8    |        |
| Yes                    | 478 (6.5)   | 843 (8.5)   |        | 50.6    | 49.8    |        |
| Diabetes               |             |             | 0.099  | 0.858§  | <0.001§ | <0.001 |
| No                     | 6661 (90.8) | 9219 (93.0) |        | 34.8    | 28.1    |        |
| Yes                    | 676 (9.2)   | 689 (7.0)   |        | 36.1    | 50.4    |        |
| Number of participants | 7337        | 9908        |        | 7337    | 9908    |        |

N, number; All P-values were estimated by considering a stratified cluster sampling design.

\*Mean (standard deviation).

†P-value was estimated by using the t-test for continuous variables and  $\chi^2$  tests for categorical variables.

‡For the continuous age variable, the proportion of obesity was obtained from people aged 50-59 years to which median age for each gender belonged.

§P-value was estimated by  $\chi^2$  tests for each gender.

¶P-value was estimated from the interaction effects terms between gender and each characteristic by using the logistic analysis.



### 158 **Characteristics associated with obesity and gender differences**

159 Among men, the rate of obesity was significantly higher in participants who were married,  
160 had at least a college education, had an income in the highest quartile, had an office job, were  
161 National Health Insurance beneficiaries, had a private health insurance plan, consumed  
162 excessive alcohol, had hypertension, and had dyslipidemia (Table 1).

163 Among women, a significantly higher rate of obesity was observed in participants  
164 who were formerly married, lived in a rural area, did not go beyond elementary school, had  
165 incomes in the lowest quartile, were manual workers, were Medical Care Aid beneficiaries,  
166 had no private health insurance plan, were physically active, lacked adequate sleep, had  
167 moderate energy intake, reported very high levels of stress, had very poor self-perceived  
168 health, had hypertension, had dyslipidemia, and were diabetic. The rate of obesity differed  
169 significantly by gender with regard to all variables except for housing status, survey year,  
170 current smoking status, self-perceived stress, and had dyslipidemia.

### 172 **Adjusted associations of obesity with education and income**

173 Among men, according to the model with only main-effect terms (Model 1), the OR of  
174 obesity was 1.41 (95% CI = 1.12–1.77) in those with at least a college education compared  
175 with their counterparts who did not go beyond elementary school (Table 2). Conversely,  
176 according to the model with interaction-effect terms (Model 2), the OR was 0.05 (95% CI =  
177 0.01–0.32) among those with incomes in the highest quartile compared with those with  
178 incomes in the lowest quartile. Education alone was not significant. In terms of their  
179 association with obesity, education and income were found to interact with each other, as five  
180 combinations of educational and income levels were significant compared with their  
181 respective reference combinations.

**Table 2** Adjusted associations of education and income with obesity by gender: the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010-2012, South Korea

|                                  | Men (N=7337)       |                    | Women (N=9908)      |                    |
|----------------------------------|--------------------|--------------------|---------------------|--------------------|
|                                  | Model 1†           | Model 2‡           | Model 1†            | Model 2‡           |
|                                  | OR (95% CI)        | OR (95% CI)        | OR (95% CI)         | OR (95% CI)        |
| <b>Main effects</b>              |                    |                    |                     |                    |
| Education                        |                    |                    |                     |                    |
| Elementary school or less (EDU1) | 1.00               | 1.00               | 1.00                | 1.00               |
| Junior high school (EDU2)        | 1.41** (1.10-1.82) | 0.61 (0.06-6.56)   | 1.19 (0.98-1.44)    | 0.16* (0.03-0.89)  |
| Senior high school (EDU3)        | 1.27* (1.03-1.58)  | 0.57 (0.08-4.25)   | 0.89 (0.72-1.09)    | 0.13** (0.03-0.58) |
| College or more (EDU4)           | 1.41** (1.12-1.77) | 1.45 (0.16-13.04)  | 0.59*** (0.46-0.75) | 0.13* (0.02-0.89)  |
| Income, quartiles                |                    |                    |                     |                    |
| Lowest (INC1)                    | 1.00               | 1.00               | 1.00                | 1.00               |
| 2nd lowest (INC2)                | 1.13 (0.91-1.39)   | 0.11* (0.02-0.64)  | 0.99 (0.84-1.16)    | 1.13 (0.26-4.98)   |
| 3rd lowest (INC3)                | 1.01 (0.81-1.28)   | 0.18 (0.03-1.11)   | 0.93 (0.77-1.11)    | 1.16 (0.22-6.20)   |
| Highest (INC4)                   | 1.10 (0.87-1.39)   | 0.05** (0.01-0.32) | 0.73** (0.60-0.89)  | 1.58 (0.30-8.38)   |
| <b>Interaction effects</b>       |                    |                    |                     |                    |
| Education x Income               |                    |                    |                     |                    |
| EDU2 x INC2                      |                    | 1.91 (0.91-4.04)   |                     | 0.77 (0.44-1.33)   |
| EDU2 x INC3                      |                    | 1.88 (0.81-4.34)   |                     | 1.11 (0.60-2.06)   |

|                               |                   |                  |       |       |
|-------------------------------|-------------------|------------------|-------|-------|
| EDU2 x INC4                   | 1.72 (0.65-4.59)  | 0.51 (0.26-1.01) |       |       |
| EDU3 x INC2                   | 2.30* (1.17-4.52) | 1.58 (0.90-2.75) |       |       |
| EDU3 x INC3                   | 2.17* (1.05-4.47) | 1.34 (0.73-2.47) |       |       |
| EDU3 x INC4                   | 1.52 (0.67-3.44)  | 1.23 (0.67-2.24) |       |       |
| EDU4 x INC2                   | 2.74* (1.14-6.56) | 1.08 (0.49-2.39) |       |       |
| EDU4 x INC3                   | 3.00* (1.27-7.12) | 0.87 (0.38-2.00) |       |       |
| EDU4 x INC4                   | 2.65* (1.04-6.78) | 0.66 (0.27-1.58) |       |       |
| Hosmer-Lemeshow test, p Value | 0.967             | 0.530            | 0.304 | 0.471 |

N, number; OR, odds ratio; CI, confidence interval; All models were adjusted for age, marital status, residential area, occupation, housing status, universal health insurance, private health insurance, survey year, smoking, alcohol consumption, routine physical exercise, daily sleep duration, daily energy intake, self-perceived stress, self-perceived health, hypertension, dyslipidemia, and diabetes; All estimates were obtained by considering a stratified cluster sampling design.

\* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

†Models 1 included only main effects terms for all variables.

‡Models 2 included both main effects terms and two-way interaction effects terms for all variables.

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4 182 Among women, according to Model 1, the OR was 0.59 (95% CI = 0.46–0.75) in  
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6 183 participants who had at least a college education compared with those who did not go beyond  
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8 184 elementary school, and 0.73 (95% CI = 0.60–0.89) among those with incomes in the highest  
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10 185 quartile compared with those with incomes in the lowest quartile. In contrast, according to  
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12 186 Model 2, the OR was 0.13 (95% CI = 0.02–0.89) among participants with at least a college  
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14 187 education compared with participants who did not go beyond elementary school. Income  
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16 188 alone was not significant. In terms of an interaction effect, one combination of educational  
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18 189 and income levels was marginally significant relative to the reference combination  
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22 190 ( $p = 0.053$ ).  
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### 192 **Predicted probability of being obese**

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28 193 The predicted probabilities for a participant to be obese if he or she had a particular set of  
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30 194 education and income levels were obtained from the model with only the main-effect term of  
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32 195 each independent variable (Model 1) and from the model with both the main-effect term of  
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34 196 each independent variable as well as the two-way interaction-effect terms between  
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36 197 independent variables (Model 2); these results are displayed graphically in Figures 1 and 2  
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38 198 for men and women, respectively.  
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44 200 **Figure 1** Predicted probabilities of being obese (and their 95% confidence intervals)  
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46 201 by education for each income level in men in a model with only main effects (A) and a model  
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48 202 with both main and interaction effects (B): the Fifth Korea National Health and Nutrition  
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50 203 Examination Survey (KNHANES V), 2010–2012, South Korea  
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54 205 **Figure 2** Predicted probabilities of being obese (and their 95% confidence intervals)

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4 206 by education for each income level in women in a model with only main effects (A) and a  
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6 207 model with both main and interaction effects (B): the Fifth Korea National Health and  
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8 208 Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea  
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13 210 According to Figures 1 and 2, the predicted probabilities of being obese differed  
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15 211 greatly between Models 1 and 2 for each gender. Whether for men or for women, the pattern  
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17 212 of the changes in the predicted probability for each income level was uniform across  
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19 213 educational levels in Model 1 (the left panel in each figure), suggesting that the income  
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21 214 differences in obesity are constant towards higher education. However, according to Model 2  
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23 215 for each gender (the right panel in each figure), the pattern became very different from that in  
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25 216 Model 1 for each gender and showed clear gender differences. For example, for men, the  
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27 217 income difference in obesity was the largest in participants who did not go beyond  
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29 218 elementary school (0.130) and the smallest in junior high school graduates (0.024), whereas  
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31 219 for women, the income difference in obesity was the largest in junior high school graduates  
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33 220 (0.199), the second largest in participants who had at least a college education (0.126) and the  
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35 221 smallest in senior high school graduates (0.052). This suggests cautiously that unlike in  
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37 222 women, the income differences in obesity decreases towards higher education in men.  
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41 223 Meanwhile, with respect to the education difference in obesity, it was the largest in  
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43 224 participants who had income in the second lowest quartile (0.148), the second largest in those  
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45 225 with income in the third lowest quartile (0.147), and the smallest in participants who had  
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47 226 income in the lowest quartile (0.090); but for women, it was the largest in participants who  
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49 227 had income in the highest quartile (0.198), the second largest in participants who had income  
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51 228 in the lowest quartile (0.196), and the smallest in those with income in the second lowest  
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53 229 quartile (0.125). This suggests cautiously that the education differences in obesity show an  
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4 230 inverse U-shape with higher income in men, in a sharp contrast with women having a U-  
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6 231 shape.

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8 232 The Findings in men can be summarized as follows: 1) Although men in two income  
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10 233 categories (the second lowest quartile and the lowest quartile) had the highest and the lowest  
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12 234 predicted probabilities across all educational levels in Model 1 respectively, no income level  
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14 235 had these distinctions with respect to all educational levels in Model 2. 2) The education-  
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16 236 income group with the highest predicted probability according to Model 1 and 2 differed: it  
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18 237 was junior high school graduates with incomes in the second lowest quartile in Model 1  
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20 238 (predicted probability = 0.392), but it was junior high school graduates with incomes in the  
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22 239 lowest quartile in Model 2 (predicted probability = 0.414). 3) The education-income group  
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24 240 with the lowest predicted probability also differed between Models 1 and 2: it was  
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26 241 participants who did not go beyond elementary school and who had incomes in the lowest  
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28 242 quartile in Model 1 (predicted probability = 0.292), but it was those did not go beyond  
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30 243 elementary school and who had incomes in third lowest quartile in Model 2 (predicted  
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32 244 probability = 0.243). 4) The gradient (or range) between the highest and lowest predicted  
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34 245 probabilities was 0.099 in Model 1 but 0.172 in Model 2.

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39 246 Likewise, the findings in women can be summarized as follows. 1) Although women  
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41 247 in two income levels (the lowest quartile and the highest quartile) had the highest and the  
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43 248 lowest predicted probabilities across all educational levels in Model 1 respectively, no  
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45 249 income level had these distinctions in Model 2. 2) The education-income group with the  
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47 250 highest predicted probability differed between Models 1 and 2: it was junior high school  
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49 251 graduates with incomes in the lowest quartile in Model 1 (predicted probability = 0.370), but  
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51 252 it was participants who did not go beyond elementary school and who had incomes in the  
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53 253 lowest quartile in Model 2 (predicted probability = 0.487). 3) The education-income group

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4 254 with the lowest predicted probability was the same in Models 1 and 2: it was those with at  
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6 255 least a college education with incomes in the highest quartile in Model 1 (predicted  
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8 256 probability = 0.183) and Model 2 (predicted probability = 0.218). 4) The gradient in the  
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10 257 predicted probability was 0.187 in Model 1 and 0.269 in Model 2.  
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## 15 16 259 **DISCUSSION**

### 17 18 260 **Comparison to previous studies**

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20 261 Although socioeconomic status has often been shown to be a significant predictor of obesity,  
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22 262 previous studies on the relationship between socioeconomic status and obesity focused on the  
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24 263 main-effect terms of independent variables, rather than both the main-effect terms of the  
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26 264 variables and their interaction-effect terms.<sup>1-3</sup>

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29 265 Under this study limitation of including only the main-effect terms of independent  
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31 266 variables, the literature has shown various inconsistencies regarding the relationship between  
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33 267 a socioeconomic status indicator and obesity in either gender or between genders. The results  
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35 268 of the previous studies were inconsistent mainly according to whether the relationship  
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37 269 between the socioeconomic status indicator and obesity was found to be positive, negative, or  
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39 270 insignificant for each gender. As for education, for example, the relationship between  
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41 271 education and obesity was found to be: positive in both men and women in Finland<sup>20</sup> and  
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43 272 India;<sup>21</sup> positive in men but negative in women in the USA<sup>22</sup> and Iran;<sup>23</sup> positive in men but  
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45 273 insignificant in women in the USA<sup>24</sup> and Peru;<sup>25</sup> insignificant in men but negative in women  
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47 274 in the USA<sup>26</sup> and Italy;<sup>27</sup> and insignificant in both men and women in the Netherlands<sup>28</sup> and  
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49 275 Finland.<sup>29</sup>

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54 276 As for income, the relationship between income and obesity was found to be:

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4 277 positive in both men and women in the USA<sup>30</sup> and Sri Lanka;<sup>31</sup> positive in men but  
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6 278 insignificant in women in the USA<sup>32</sup> and South Korea;<sup>33</sup> insignificant in men but negative in  
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8 279 women in Singapore<sup>34</sup> and Canada;<sup>35</sup> and insignificant in both men and women in the USA,<sup>26</sup>  
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10 280 Canada,<sup>35</sup> Greece,<sup>36</sup> and China.<sup>37</sup>

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12 In particular, many studies indicated that socioeconomic status and obesity are  
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14 281 negatively correlated in both men and women in developed countries,<sup>1,2</sup> being consistent for  
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16 282 both education and income, as shown in France<sup>4</sup> and the USA<sup>5</sup> for education; and in  
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18 283 Australia<sup>6</sup> and the USA<sup>7</sup> for income.  
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22 285 Considering the interaction-effect terms between independent variables, however, the  
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24 286 results of our study suggest that in certain developed countries like South Korea, education  
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26 287 and income may not have negative associations with obesity in either men or women and  
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28 288 they may have somewhat complex relationships with obesity because of the interaction  
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30 289 effects between independent variables.  
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33 290 This suggestion is depicted clearly in both Table 2 and Figures. In models including  
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35 291 the main-effect terms of all independent variables considered in this study and their two-way  
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37 292 interaction-effect terms in Table 2, the main-effect of income as well as the interaction-effect  
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39 293 term between education and income was significant in men, but only the main-effect term of  
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41 294 education was significant in women. It seems that in men, income plays a role in its  
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43 295 association with obesity on its own as well as through its interaction with education, whereas  
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45 296 education plays a role only through its interaction with income; in women, however,  
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47 297 education plays a role in its association with obesity on its own, despite no role for income.  
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50 298 Further, complex relationships between each of the education and income levels with  
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52 299 obesity are suggested in Figures 1 and 2. In models including main-effect terms of all  
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54 300 independent variables and their two-way interaction-effect terms (as shown in the right panels



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4 301 denoted as B in figures), the differences in the predicted probability of being obese between  
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6 302 income levels at a certain education level varied markedly between education levels, and their  
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8 303 gender differences were very evident. Furthermore, people with a particular set of education  
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10 304 and income levels showing the highest (or lowest) risk of obesity, in terms of the predicted  
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12 305 probability of being obese, changed after including the two-way interaction-effect terms for  
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14 306 each gender.  
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17 307 Therefore, the results of our study may caution researchers considering only the  
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19 308 main-effect terms in studies of the associations of education and income with obesity to be  
20  
21 309 very careful about interpreting their results. The reasons are as follows: 1) studies considering  
22  
23 310 only the main-effect terms may come to incorrect conclusions about the roles of education  
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25 311 and income; 2) those studies may fail to explore how the income differences in obesity at an  
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27 312 education level are different from those at another education level (or how the education  
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29 313 differences in obesity at an income level are different from those at another income level);  
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31 314 and 3) those studies may result in the incorrect identification of the education-income group  
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33 315 having the highest (or lowest) risk of obesity.  
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37 316 In addition, according to the results of our study of South Korea, the aforementioned  
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39 317 well-known negative association between socioeconomic status and obesity in developed  
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41 318 countries should be re-examined using models incorporating interaction-effect terms among  
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43 319 various characteristics. Similar results were obtained with regard to abdominal obesity as  
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45 320 those reported here for general obesity (these results are available on request).  
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### 50 322 **Plausible mechanisms**

51 323 Based on these results, this study aimed to answer the following three questions. First, who  
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53 324 are the participants belonging to the particular set of education and income levels showing the  
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4 325 highest and lowest values of the predicted probabilities of being obese for each gender and  
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6 326 why social positioning leads women to show strong educational differences in models  
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8 327 accounting for joint income effects, whereas men show strong income differences alone and  
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10 328 in combination with education?

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12  
13 329 To examine this, we provided Supplementary Tables 1 and 2, which show the  
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15 330 distributions of sample characteristics by education and income for men and women,  
16  
17 331 respectively. For men, as shown in the right panel of Figure 1, the highest predicted  
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19 332 probability of being obese was shown in junior high school graduates with incomes in the  
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21 333 lowest quartile (predicted probability = 0.414), whereas the lowest predicted probability in  
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23 334 participants those who did not go beyond elementary school and who had incomes in third  
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25 335 lowest quartile (predicted probability = 0.243). Relative to the education-income group  
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27 336 showing the lowest predicted probability of being obese, the group showing the highest  
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29 337 predicted probability tended to have more than twice as high as proportion in participants  
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31 338 who were formerly married, participants who were never-married, residents in non-metro  
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33 339 urban areas, manual workers, participants surveyed in 2010, current smokers, participants  
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35 340 who had energy intake at a moderate level, participants who reported that their health was  
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37 341 very bad, participants having hypertension, and participants having diabetes (Supplementary  
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39 342 Table 1).

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44 343 Likewise, for women, as shown in the right panel of Figure 2, the highest predicted  
45  
46 344 probability of being obese was shown in participants who did not go beyond elementary  
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48 345 school and who had incomes in the lowest quartile (predicted probability = 0.487), whereas  
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50 346 the lowest predicted probability in participants with at least a college education with incomes  
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52 347 in the highest quartile (predicted probability = 0.218). Compared to the education-income  
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54 348 group showing the lowest predicted probability of being obese, the group showing the highest

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4 349 predicted probability tended to have more than twice as high as proportion in participant who  
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6 350 were formerly married, residents in rural areas, participants who were unemployed,  
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8 351 participants whose daily sleep duration were short, participants who reported that their stress  
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10 352 was very high, participants who reported that their health was very bad, participants having  
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12 353 hypertension, participants having dyslipidemia, and participants having diabetes  
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15 354 (Supplementary Table 2).

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17 355 This comparison suggests that a participant's belonging to a particular one of  
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19 356 different education-income groups (that is, a social position) is associated with a particular  
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21 357 risk of obesity. A variety of studies on social position have shown that one's social position  
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23 358 may be determined exogenously or endogenously.<sup>38 39</sup> An individual can be placed in a social  
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25 359 position (or social status) within a society before or at birth. This is called ascribed status.  
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27 360 Ascribed statuses, which differ across societies, exist in all societies. Ascribed statuses  
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29 361 depend on genetics, gender, age, race, or family characteristics. Alternately, an individual can  
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31 362 achieve his or her social position by his or her own efforts, which is called achieved status.  
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33 363 Achieved statuses are social position which he or she acquires after his or her birth as  
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35 364 consequences of the exercise of knowledge, ability and skill, personal perseverance, and  
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37 365 active interactions with others. Both education and income provides examples of social  
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39 366 position that may be either ascribed or achieved status. Meanwhile, when comparing men and  
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41 367 women, if education is more of an ascribed status rather than an achieved status, compared to  
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43 368 the income, then education is more likely to make a positive contribution to income in  
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45 369 women compared to that in men. Then the role of education on obesity may overtake that of  
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47 370 income on obesity in women compared to men. Meanwhile, income in combination with  
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49 371 education rather than education alone may influence the risk of obesity in men. It seems  
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51 372 definite that further research is necessary to evaluate the relationship between social position  
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4 373 and obesity.

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6 374 Second, with regard to its association with obesity, why does education sometimes  
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8 375 interact with income and why does the interaction differ by gender? This study believes that  
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10 376 two different factors may be involved in this issue. More education may discourage obesity  
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12 377 insofar as it promotes a more efficient use of health-related services and products<sup>40 41</sup> and an  
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14 378 enhanced sense of control and empowerment.<sup>42 43</sup> In addition, and less directly, more  
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16 379 education may contribute to a higher income, which may discourage obesity by increasing  
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18 380 access to higher quality food and better medical care.<sup>40 41</sup> However, in a subgroup of people  
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20 381 (e.g., men with certain sociocultural characteristics), a higher income may be positively  
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22 382 associated with obesity even though more education leads to higher income. Thus, more  
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24 383 education and a higher income may lead to a higher likelihood of being obese among this  
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26 384 subgroup of people. Meanwhile, it is interesting to note that gender may modify the effects of  
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28 385 education and income on one's health. Previous research has suggested that gender,<sup>44</sup> race,<sup>45</sup>  
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30 386 place<sup>45 46</sup> and their intersections<sup>47 48</sup> alter the effects of education and income on health. A  
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32 387 recent study compared race-gender groups to examine the effects of baseline education and  
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34 388 income on sustained health problems in five domains (depressive symptoms, insomnia,  
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36 389 physical inactivity, BMI, and self-rated health) using the Health and Retirement Study in the  
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38 390 US.<sup>47</sup> This study found that the interaction of race and gender changed the protective effects  
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40 391 of social determinants on sustained health problems such as insomnia, physical inactivity, and  
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42 392 BMI. Another study showed that gender modifies the effects of education and income on  
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44 393 psychosocial well-being of patients with chronic conditions.<sup>44</sup>

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46 394 It is generally known that women with a high level of education tend to be more  
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48 395 worried about weight control than men with the same level of education.<sup>49</sup> This may be  
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50 396 because obese women may be more penalized with regard to employment opportunities,<sup>50</sup>

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4 397 wage equality,<sup>51</sup> and finding marriage partners than obese men.<sup>52</sup> On the other hand, even  
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6 398 men with a high income tend to feel more comfortable being overweight than do women in  
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8 399 the same income group.<sup>53</sup> This can be explained in part by the notion of habitus and  
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10 400 Bourdieu's theory, which states that the body has a symbolic value in size and shape for  
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12 401 people, but that valuations of the body differ by gender.<sup>54 55</sup>

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15 402 Even in a developed society such as South Korea, men have more political and  
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17 403 economic influence and are the primary wage earners for families, and most jobs tend to be  
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19 404 awarded first to men. Gender differences in body image are also pronounced in South Korea:  
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21 405 according to an international study of body image and weight control in young, educated  
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23 406 adults, the age-adjusted prevalence of feeling overweight was the second lowest in Korean  
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25 407 men (14%) compared with that in men in the other 22 countries, but the prevalence of seeing  
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27 408 oneself as overweight was the highest in Korean women (77%).<sup>53</sup> Thus, local culture and  
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29 409 norms put greater pressure on women than on men to lose weight, as indicated in previous  
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31 410 studies.<sup>53 56 57</sup>

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35 411 As a third question to be raised from the results of this study, after including the  
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37 412 interaction-effect terms in this study, why did the predicted probabilities of being obese  
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39 413 follow erratic rather than uniform patterns for both education and income levels, and why  
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41 414 were there gender differences in this regard? One reason for the erratic patterns in the  
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43 415 predicted probabilities might be that education or income may interact with some other  
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45 416 covariate(s). For example, the association between obesity and income may be influenced by  
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47 417 stress level in men<sup>58</sup> and health behaviors caused by a high level of stress, such as smoking  
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49 418 cigarettes and drinking alcohol, thereby contributing to the positive association between  
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51 419 socioeconomic status and obesity in men.<sup>59 60</sup> Meanwhile, previous studies investigated the  
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53 420 relationship among contextual factors (e.g. gender, race, class, and place), psychosocial

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4 421 factors and obesity factors (e.g. obesity and BMI).<sup>61 62 63 64 65</sup> Using data from the Health and  
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6 422 Retirement Study in the US, a study showed that the association between sustained health  
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8 423 problems such as depression and obesity are not universal across race and gender groups.<sup>62</sup>  
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10 424 This suggests that culture connected to race and gender may influence cognitive and  
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12 425 emotional elements that are essential for the perception of obesity and associated weight  
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14 426 management behaviors.<sup>66</sup>

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17 427 Another reason may be that, although education or income interacts with a covariate,  
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19 428 different combinations between levels of education or income and covariate categories may  
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21 429 be differently associated with being obese.

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24 430 There are three potential reasons for the gender differences in the predicted  
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26 431 probabilities of being obese for both education and income levels. First, these gender  
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28 432 differences partly derive from gender differences in the covariates that interact with education  
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30 433 or income. For example, in the present study, educational level showed significant interaction  
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32 434 effects with residential area, excessive alcohol consumption, self-perceived stress, self-  
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34 435 perceived health, and survey year in men, whereas women's educational level interacted  
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36 436 significantly with age, marital status, housing status, hypertension, and diabetes (results not  
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38 437 shown). Second, although covariates interact with education or income in both men and  
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40 438 women, the magnitude of the interactions between the covariate categories and levels of  
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42 439 education or income might differ by gender. Previous studies showed that, unlike in women,  
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44 440 increased income does not result in an equivalent adaptation to healthier behaviors in men.<sup>32</sup>  
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46 441 Finally, there may be gender differences in the reverse causation between education or  
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48 442 income and obesity. For example, in certain patriarchal societies, girls with a health problem  
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50 443 may be less likely to have a high level of education than their male counterparts.<sup>67</sup>  
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4 445 **An extended study of women**

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6 446 Unlike men, because women may be subject to the effects of pregnancy and breastfeeding, it  
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8 447 would be worthwhile to take women-specific characteristics into consideration and construct  
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10 448 a new sample of women, and compare their results with the results obtained from the men's  
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12 449 sample. Therefore, we extended our study with a special consideration of women as follows:  
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14 450 1) to construct a new sample of women, we excluded pregnant women (n=120) or breast-  
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16 451 feeding women (n=188) from the analysis, because their bodyweight can be affected by  
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18 452 childbearing; 2) we further categorized women according to their menopausal status and  
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20 453 included that status as an additional covariate (where not-menopausal was the reference  
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22 454 group), because menopause may be associated with obesity;<sup>68</sup> with the new sample of 9,692  
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24 455 women, we conducted all the analytic procedures included in the materials and methods  
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26 456 chapter; and, finally, we provided the results in Supplementary Tables 3 and 4 and  
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28 457 Supplementary Figure 1.  
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33 458 According to the results, the differences in the proportion and the obesity rate among  
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35 459 all characteristics were very similar between the prior sample of women and the new sample  
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37 460 (Table 1 and Supplementary Table 3). Regarding menopausal status in the new sample, in  
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39 461 comparison with women who were not menopausal, menopausal women were higher in their  
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41 462 proportion (57.0% vs. 48.0%) and showed a significant, higher rate of obesity (37.6% vs.  
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43 463 21.6%).  
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46 464 In the model with only main-effect terms (Model 1), the OR of obesity was 0.60 (95%  
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48 465 CI = 0.46–0.77) in those with at least a college education compared with their counterparts  
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50 466 who did not go beyond elementary school; and the OR was 0.73 (95% CI = 0.59–0.89)  
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52 467 among those with incomes in the highest quartile compared with those with incomes in the  
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54 468 lowest quartile (Supplementary Table 4). These results were also very similar to those  
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4 469 obtained from the prior sample (Table 2).  
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6 470 Meanwhile, according to the model with interaction-effect terms (Model 2), neither  
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8 471 education alone nor income alone was significant. Instead, education and income were found  
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10 472 to interact with each other in relation to obesity, as the two combinations of educational and  
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12 473 income levels were significant when compared with their respective reference combinations.  
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14 474 These results are different from those obtained from the prior sample (Table 2): in that  
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16 475 sample, education alone was significant, whereas neither income alone nor any interaction-  
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18 476 effect term between education and income was significant.  
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21 477 The pattern of the changes in the predicted probability of being obese for each  
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23 478 income level across educational levels in Model 1 and Model 2 (Supplementary Figure 1)  
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25 479 appears very similar to those obtained from the prior sample (Figure 2). In details, however,  
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27 480 the predicted probabilities of being obese changed slightly in the new sample: for example,  
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29 481 the highest predicted probability of being obese was shown in participants who did not go  
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31 482 beyond elementary school and who had incomes in the lowest quartile in both the prior  
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33 483 sample and the new sample, but the predicted probability was 0.487 in the prior sample and  
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35 484 0.488 in the new sample.  
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39 485 In summary, the extended study of women suggests that whether or not the sample of  
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41 486 women in the studies of obesity considers women-specific characteristics which may be  
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43 487 related to obesity, these studies need to include the interaction effects of independent  
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45 488 variables to explore precisely the associations between education and income in relation to  
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47 489 obesity.  
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### 52 53 491 **Public health implications**

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55 492 From a policy perspective, it is of interest whether as a government attempts to provide



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4 493 people with the highest level of education, its actions can lead to a reduction in the  
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6 494 prevalence of obesity and the socioeconomic gradient in such prevalence. Though caution is  
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8 495 required when making policy predictions based on findings from cross-sectional data,  
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10 496 according to the findings of this study, the answer might be “no.” An enhanced governmental  
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12 497 educational policy that enables all men to complete the highest level of formal education  
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14 498 would reduce the gradient in the predicted probability of being obese by 53%, from 0.130 to  
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16 499 0.061, but would also increase the average predicted probability by 26%, from 0.287 to 0.362.  
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18 500 Conversely, the same enhanced educational policy in women would raise the gradient in the  
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20 501 predicted probability by 77%, from 0.071 to 0.126, but would lower the average predicted  
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22 502 probability by 36%, from 0.440 to 0.283. This suggests that, in order to meet both goals (low  
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24 503 prevalence of obesity and reduced gradient by socioeconomic status), educational policies  
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26 504 should be implemented in combination with other social policies, and these governmental  
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28 505 efforts should be differentiated by gender. These results may elicit a new debate about  
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30 506 whether educational policies should consider health consequences.<sup>69 70</sup> Meanwhile, some  
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32 507 cross-country studies have shown that the determinants of health particularly the effects of  
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34 508 social determinants are specific to countries and have emphasized the need for local studies  
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36 509 that inform local policies and programs.<sup>46 71 72</sup>  
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#### 44 **Strengths and limitations**

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46 512 This study analyzed data from a nationally representative sample of South Korean adults,  
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48 513 providing abundant information about anthropometric measures, socio-demographic  
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50 514 characteristics, lifestyle behaviors, and medical conditions. Using a quantified prediction, this  
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52 515 study shows what would happen if policies to reduce obesity prevalence did not consider  
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54 516 complex interactions among the characteristics of individuals. Above all, this study is the first  
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4 517 to address the association of socioeconomic status with obesity while considering both the  
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6 518 main-effect term of each independent variable and the two-way interaction-effect terms  
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8 519 between independent variables. We believe that our research findings can be generalizable to  
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10 520 settings other than those in South Korea because: our research included a broad range of  
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12 521 participants from a nationally representative sample of the South Korean population through  
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14 522 the KNHANES; the nature and level of education, income, and covariates can be comparable;  
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16 523 and the definition of general obesity can be relevant to other settings or countries.  
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19 524         However, this study has several limitations. The cross-sectional study design  
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21 525 precludes causal inferences about the relationship between socioeconomic status and obesity.  
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23 526 Moreover, the data were collected by a self-report survey, which may have resulted in  
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25 527 measurement error and recall bias. Although it is beyond the scope of this study, it would be  
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27 528 of great interest to explore gender-specific interactions among education, income and other  
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29 529 socioeconomic status indicators like occupation, home-ownership and marital status. Other  
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31 530 potential covariates, such as genetics, social network, parity, and parental obesity, were not  
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33 531 included in analyses because these data were not available. Unobserved factors, such discount  
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35 532 rate and risk aversion, may have influenced both socioeconomic status and body weight.<sup>73 74</sup>  
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38 533 Finally, we also could not incorporate race and ethnicity into our analysis because the  
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40 534 KNHANES did not include these data, and moreover, because the absolute majority of the  
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42 535 population is of Korean ethnicity.<sup>75 76</sup>  
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## 48 537 **CONCLUSIONS**

49 538 This is the first study to investigate the association of socioeconomic status with obesity  
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51 539 while considering both the main-effect term of each independent variable and the two-way  
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4 540 interaction- effect terms between independent variables. This study highlights the importance  
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6 541 of interaction effects in studies of the associations of socioeconomic status with obesity.  
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8 542 According to the results, moving from models evaluating only main effects to models  
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10 543 evaluating both main and interaction effects may change the association of socioeconomic  
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12 544 status with obesity, the group with the highest likelihood of obesity, the gradient in the  
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14 545 likelihood of obesity by socioeconomic status, and gender differences in the associations of  
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16 546 socioeconomic status with obesity. These results suggest that studies on the association  
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18 547 between socioeconomic status and obesity should include interaction-effect terms for all  
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20 548 characteristics and consider gender differences, and that policy efforts to reduce obesity and  
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22 549 the resulting socioeconomic gradients should be established based on the results of those in-  
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24 550 depth studies. Moreover, further research is needed to examine whether these findings are  
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26 551 valid in other sociocultural settings.  
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## Contributors

WC conceived and designed the study, conducting the literature review and the statistical analysis, writing the paper. JK collected and managed the data. JK, SJL, SL, and RK participated in reviewing the literature and writing the paper.

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## Competing interests

None declared.

## Ethics approval

Institutional Review Board of Yonsei University Graduate School of Public Health.

## Provenance and peer review

Not commissioned; externally peer reviewed.

## Data sharing statement

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4 The data used in this study are available from the Korean Centers for Disease Control and  
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6 Prevention database.  
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For peer review only

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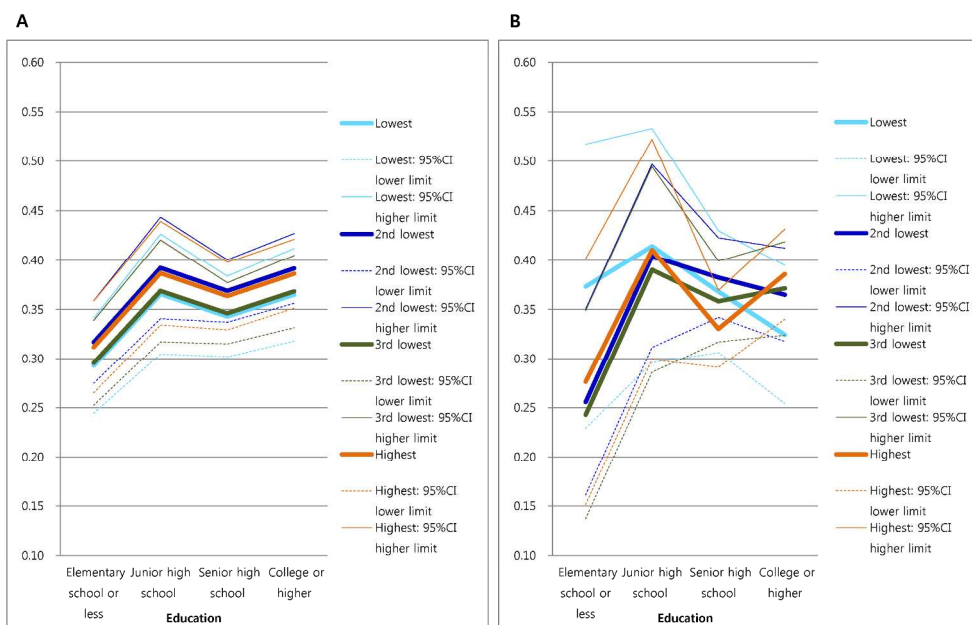


Figure 1 Predicted probabilities of being obese (and their 95% confidence intervals) by education for each income level in men in a model with only main effects (A) and a model with both main and interaction effects (B): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea

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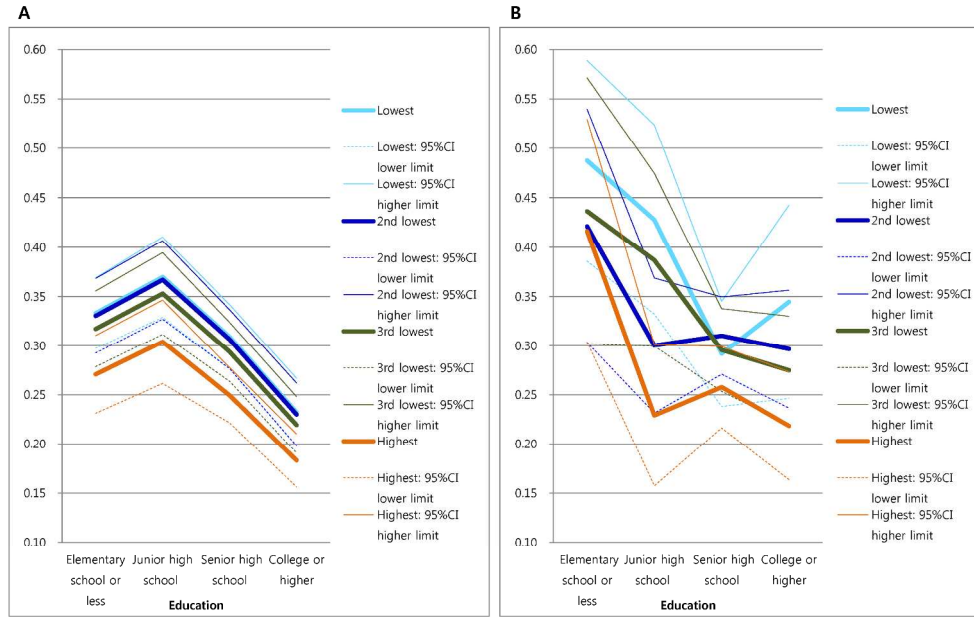


Figure 2 Predicted probabilities of being obese (and their 95% confidence intervals) by education for each income level in women in a model with only main effects (A) and a model with both main and interaction effects (B): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea

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**Table S1** Distribution (%) of sample characteristics in men by education and income (quartiles): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010-2012, South Korea

| Characteristic                   | Overall | Elementary school or less |         |         |      |        | Junior high school |         |         |      |        | Senior high school |         |         |      |        | College or more |         |         |      |        | (Total) |
|----------------------------------|---------|---------------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|-----------------|---------|---------|------|--------|---------|
|                                  |         | Low                       | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low             | 2nd low | 3rd low | High | (Sum)  |         |
| Age, years *                     | 50.8    | 70.5                      | 64.4    | 62.3    | 61.8 | (67.2) | 63.8               | 58.0    | 57.2    | 61.8 | 59.6   | 53.0               | 44.9    | 45.1    | 45.8 | 46.4   | 48.7            | 42.9    | 42.4    | 61.8 | 44.0   |         |
| Marital status                   |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Married                          | 79.7    | 10.6                      | 4.9     | 2.7     | 1.7  | (19.9) | 4.3                | 3.9     | 2.7     | 2.2  | (13.1) | 5.6                | 9.6     | 8.4     | 8.7  | (32.3) | 2.3             | 8.0     | 10.0    | 14.4 | (34.8) | (100.0) |
| Formerly married                 | 4.6     | 22.7                      | 8.9     | 1.8     | 2.1  | (35.4) | 11.2               | 4.1     | 2.1     | 2.4  | (19.8) | 11.5               | 7.1     | 4.7     | 5.5  | (26.8) | 5.3             | 3.8     | 4.1     | 4.7  | (18.0) | (100.0) |
| Never-married                    | 15.7    | 0.5                       | 0.4     | 0.1     | 0.0  | (1.0)  | 1.0                | 0.9     | 0.5     | 0.5  | (2.9)  | 9.7                | 16.2    | 14.0    | 15.8 | (55.7) | 5.7             | 8.3     | 11.7    | 14.8 | (40.5) | (100.0) |
| Residential area                 |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Metro urban                      | 44.2    | 6.1                       | 3.5     | 1.8     | 1.0  | (12.4) | 2.9                | 3.5     | 2.4     | 2.1  | (10.9) | 6.6                | 10.9    | 8.9     | 9.7  | (36.0) | 3.6             | 8.1     | 11.3    | 17.8 | (40.8) | (100.0) |
| Non-metro urban                  | 34.4    | 7.1                       | 3.7     | 1.7     | 1.4  | (14.0) | 4.0                | 3.0     | 2.0     | 1.6  | (10.6) | 6.0                | 10.7    | 10.9    | 10.2 | (37.8) | 2.6             | 9.8     | 11.4    | 14.0 | (37.7) | (100.0) |
| Rural                            | 21.4    | 20.5                      | 7.3     | 4.3     | 2.4  | (34.4) | 6.5                | 4.1     | 2.9     | 2.4  | (15.8) | 7.2                | 9.5     | 6.6     | 8.1  | (31.5) | 2.3             | 4.5     | 5.2     | 6.4  | (18.3) | (100.0) |
| Occupation,                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Unemployed                       | 25.6    | 9.8                       | 6.5     | 3.6     | 2.1  | (22.0) | 4.4                | 5.2     | 3.8     | 3.1  | (16.6) | 6.1                | 13.7    | 10.9    | 11.9 | (42.5) | 1.8             | 5.1     | 5.5     | 6.6  | (18.9) | (100.0) |
| Office worker                    | 26.8    | 0.3                       | 0.1     | 0.3     | 0.3  | (0.9)  | 0.4                | 0.3     | 0.5     | 0.8  | (1.8)  | 1.7                | 6.0     | 6.5     | 7.8  | (22.0) | 3.5             | 14.8    | 21.9    | 35.1 | (75.3) | (100.0) |
| Manual worker                    | 47.6    | 18.7                      | 5.0     | 2.0     | 1.4  | (27.0) | 7.3                | 3.5     | 1.5     | 1.1  | (13.5) | 12.5               | 9.4     | 8.4     | 7.0  | (37.2) | 4.6             | 5.9     | 6.0     | 5.8  | (22.3) | (100.0) |
| Housing status, home owner       | 76.4    | 9.9                       | 4.9     | 2.7     | 1.7  | (19.2) | 3.9                | 3.4     | 2.5     | 2.2  | (12.0) | 5.1                | 9.5     | 9.1     | 10.6 | (34.3) | 2.2             | 7.0     | 10.1    | 15.3 | (34.6) | (100.0) |
| Universal health insurance, NHI  | 98.2    | 9.1                       | 4.4     | 2.3     | 1.4  | (17.2) | 3.9                | 3.4     | 2.4     | 2.0  | (11.7) | 6.3                | 10.6    | 9.2     | 9.7  | (35.8) | 2.8             | 8.0     | 10.2    | 14.3 | (35.3) | (100.0) |
| Private health insurance, holder | 69.2    | 3.2                       | 3.0     | 2.1     | 1.5  | (9.7)  | 2.0                | 3.4     | 2.6     | 2.3  | (10.2) | 4.1                | 11.1    | 10.7    | 12.0 | (37.9) | 2.3             | 9.2     | 12.7    | 18.1 | (42.2) | (100.0) |
| Survey year                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| 2010                             | 35.3    | 9.7                       | 4.4     | 2.2     | 1.4  | (17.6) | 4.4                | 3.1     | 2.5     | 2.3  | (12.3) | 6.3                | 11.7    | 9.2     | 7.8  | (35.0) | 3.4             | 8.3     | 10.9    | 12.4 | (35.1) | (100.0) |
| 2011                             | 34.0    | 9.6                       | 4.2     | 2.1     | 1.6  | (17.5) | 3.7                | 4.2     | 2.2     | 2.0  | (12.0) | 5.9                | 10.0    | 8.9     | 10.8 | (35.6) | 2.5             | 8.2     | 9.0     | 15.2 | (34.8) | (100.0) |

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**Table S2** Distribution (%) of sample characteristics in women by education and income (quartiles): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010-2012, South Korea

| Characteristic                   | Overall | Elementary school or less |         |         |      |        | Junior high school |         |         |      |        | Senior high school |         |         |      |        | College or more |         |         |      |        | (Total) |
|----------------------------------|---------|---------------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|--------------------|---------|---------|------|--------|-----------------|---------|---------|------|--------|---------|
|                                  |         | Low                       | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low                | 2nd low | 3rd low | High | (Sum)  | Low             | 2nd low | 3rd low | High | (Sum)  |         |
| Age, years *                     | 50.5    | 69.3                      | 64.2    | 63.4    | 64.9 | (67.0) | 59.6               | 55.4    | 54.9    | 54.6 | (56.2) | 43.7               | 41.4    | 42.9    | 43.0 | (42.6) | 38.5            | 35.9    | 36.2    | 39.1 | (37.5) |         |
| Marital status                   |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Married                          | 69.5    | 13.6                      | 6.8     | 4.0     | 3.0  | (27.3) | 2.6                | 3.6     | 3.1     | 2.8  | (12.1) | 3.6                | 10.5    | 9.3     | 10.5 | (33.9) | 1.2             | 5.9     | 7.8     | 11.8 | (26.7) | (100.0) |
| Formerly married                 | 18.2    | 45.2                      | 12.0    | 6.8     | 6.9  | (71.0) | 3.9                | 2.9     | 1.6     | 1.4  | (9.8)  | 6.3                | 4.2     | 2.1     | 2.2  | (14.9) | 1.3             | 0.9     | 1.1     | 1.0  | (4.3)  | (100.0) |
| Never-married                    | 12.3    | 0.3                       | 0.1     | 0.0     | 0.2  | (0.6)  | 0.5                | 0.3     | 0.2     | 0.1  | (1.1)  | 8.7                | 12.0    | 9.4     | 13.6 | (43.7) | 3.9             | 12.7    | 15.8    | 22.3 | (54.7) | (100.0) |
| Residential area                 |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Metro urban                      | 44.5    | 12.2                      | 5.8     | 3.6     | 2.6  | (24.3) | 2.5                | 3.0     | 2.4     | 2.4  | (10.3) | 5.3                | 9.9     | 8.0     | 10.9 | (34.1) | 1.7             | 6.5     | 8.8     | 14.2 | (31.3) | (100.0) |
| Non-metro urban                  | 35.0    | 13.9                      | 6.3     | 3.7     | 3.0  | (26.8) | 2.8                | 2.9     | 2.5     | 2.2  | (10.4) | 4.9                | 10.9    | 9.6     | 9.6  | (35.0) | 1.8             | 6.4     | 8.6     | 11.0 | (27.8) | (100.0) |
| Rural                            | 20.5    | 36.3                      | 10.2    | 5.5     | 5.4  | (57.4) | 2.5                | 3.5     | 2.5     | 1.8  | (10.3) | 3.4                | 6.5     | 5.1     | 5.7  | (20.7) | 0.7             | 3.5     | 3.0     | 4.4  | (11.6) | (100.0) |
| Occupation,                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| Unemployed                       | 52.6    | 20.8                      | 9.5     | 5.5     | 5.0  | (40.8) | 2.9                | 4.8     | 4.5     | 4.1  | (16.2) | 5.0                | 10.8    | 8.9     | 9.2  | (33.9) | 0.8             | 2.5     | 2.3     | 3.6  | (9.2)  | (100.0) |
| Office worker                    | 16.0    | 0.4                       | 0.3     | 0.1     | 0.2  | (1.0)  | 0.4                | 0.9     | 0.2     | 0.5  | (2.0)  | 2.6                | 7.0     | 8.3     | 10.5 | (28.4) | 2.4             | 11.8    | 21.1    | 33.4 | (68.6) | (100.0) |
| Manual worker                    | 31.4    | 21.2                      | 7.3     | 4.3     | 3.3  | (36.2) | 3.1                | 2.7     | 2.0     | 1.6  | (9.3)  | 5.3                | 9.6     | 7.3     | 9.1  | (31.3) | 1.8             | 6.1     | 6.6     | 8.8  | (23.2) | (100.0) |
| Housing status, home owner       | 73.5    | 16.0                      | 7.8     | 4.7     | 4.0  | (32.5) | 2.3                | 3.1     | 2.9     | 2.6  | (10.8) | 3.2                | 8.5     | 8.3     | 10.8 | (30.8) | 1.2             | 5.2     | 7.3     | 12.2 | (25.9) | (100.0) |
| Universal health insurance, NHI  | 97.0    | 16.6                      | 7.0     | 4.1     | 3.4  | (31.1) | 2.5                | 3.1     | 2.5     | 2.3  | (10.4) | 4.3                | 9.7     | 8.2     | 9.6  | (31.8) | 1.6             | 6.0     | 7.8     | 11.4 | (26.7) | (100.0) |
| Private health insurance, holder | 70.7    | 7.7                       | 5.2     | 3.4     | 2.9  | (19.2) | 1.9                | 3.3     | 2.8     | 2.8  | (10.7) | 4.3                | 11.1    | 9.9     | 12.1 | (37.5) | 1.6             | 7.1     | 9.6     | 14.4 | (32.6) | (100.0) |
| Survey year                      |         |                           |         |         |      |        |                    |         |         |      |        |                    |         |         |      |        |                 |         |         |      |        |         |
| 2010                             | 34.0    | 17.1                      | 7.3     | 4.3     | 3.4  | (32.0) | 2.4                | 2.8     | 2.4     | 2.3  | (9.9)  | 4.9                | 10.5    | 7.9     | 8.2  | (31.5) | 1.6             | 6.0     | 8.2     | 10.8 | (26.6) | (100.0) |
| 2011                             | 34.1    | 18.1                      | 7.1     | 3.6     | 3.4  | (32.2) | 2.4                | 3.5     | 2.4     | 2.3  | (10.6) | 4.3                | 8.6     | 8.1     | 10.6 | (31.6) | 1.4             | 5.7     | 7.2     | 11.4 | (25.7) | (100.0) |

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**Table S3** Sample characteristics and their associations with obesity by gender: the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010-2012, South Korea

|                                       | Distribution, N (%) |              |          | Obesity, % |         |          |
|---------------------------------------|---------------------|--------------|----------|------------|---------|----------|
|                                       | Men                 | Women        | p Value† | Men        | Women   | p Value¶ |
| Body mass index, kg m <sup>-2</sup> * | 23.97 (3.1)         | 23.50 (3.5)  | <0.001   |            |         |          |
| Obesity                               | 2565 (35.0)         | 2896 (29.9)  | <0.001   |            |         |          |
| Age, years*                           | 50.79 (16.4)        | 50.90 (16.5) | <0.001   | 5.1‡       | 34.7‡   | <0.001   |
| Marital status                        |                     |              | <0.001   | 0.001§     | <0.001§ | <0.001   |
| Married                               | 5848 (79.7)         | 6672 (68.8)  |          | 6.0        | 30.9    |          |
| Formerly married                      | 339 (4.6)           | 1803 (18.6)  |          | 0.1        | 37.4    |          |
| Never-married                         | 1150 (15.7)         | 1217 (12.6)  |          | 1.0        | 13.4    |          |
| Residential area                      |                     |              | 0.387    | 2.259§     | <0.001§ | <0.001   |
| Metro urban                           | 3240 (44.2)         | 4315 (44.5)  |          | 5.2        | 27.2    |          |
| Non-metro urban                       | 2523 (34.4)         | 3378 (34.9)  |          | 6.6        | 29.5    |          |
| Rural                                 | 1574 (21.4)         | 1999 (20.6)  |          | 1.9        | 36.5    |          |
| Education                             |                     |              | <0.001   | 0.001§     | <0.001§ | <0.001   |
| Elementary school or less             | 1294 (17.6)         | 3167 (32.7)  |          | 6.6        | 40.2    |          |
| Junior high school                    | 867 (11.8)          | 1020 (10.5)  |          | 6.1        | 38.6    |          |
| Senior high school                    | 2617 (35.7)         | 3071 (31.7)  |          | 4.5        | 27.1    |          |
| College or more                       | 2559 (34.9)         | 2434 (25.1)  |          | 9.3        | 16.3    |          |
| Income, quartiles                     |                     |              | <0.001   | 0.002§     | <0.001§ | <0.001   |
| Lowest                                | 1694 (23.1)         | 2621 (27.1)  |          | 8.4        | 37.0    |          |
| 2nd lowest                            | 1924 (26.2)         | 2427 (25.0)  |          | 6.5        | 32.2    |          |
| 3rd lowest                            | 1739 (23.7)         | 2112 (21.8)  |          | 4.9        | 28.0    |          |
| Highest                               | 1980 (27.0)         | 2532 (26.1)  |          | 9.1        | 21.9    |          |
| Occupation                            |                     |              | <0.001   | 0.001§     | <0.001§ | <0.001   |
| Unemployed                            | 1878 (25.6)         | 5047 (52.1)  |          | 8.7        | 31.4    |          |

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|    |                            |             |             |        |        |         |        |  |
|----|----------------------------|-------------|-------------|--------|--------|---------|--------|--|
| 1  |                            |             |             |        |        |         |        |  |
| 2  |                            |             |             |        |        |         |        |  |
| 3  |                            |             |             |        |        |         |        |  |
| 4  | Office worker              | 1965 (26.8) | 1542 (15.9) |        | 22.1   | 17.6    |        |  |
| 5  | Manual worker              | 3494 (47.6) | 3103 (32.0) |        | 44.3   | 33.6    |        |  |
| 6  | Housing status             |             |             | 0.321  | 0.945§ | 0.594§  | 0.648  |  |
| 7  |                            |             |             |        |        |         |        |  |
| 8  | Home owner                 | 5606 (76.4) | 7148 (73.8) |        | 55.1   | 29.6    |        |  |
| 9  | Renter                     | 1731 (23.6) | 2544 (26.2) |        | 44.6   | 30.6    |        |  |
| 10 | Universal health insurance |             |             | <0.001 | 0.020§ | 0.005§  | <0.001 |  |
| 11 |                            |             |             |        |        |         |        |  |
| 12 | National Health Insurance  | 7204 (98.2) | 9393 (96.9) |        | 55.2   | 29.6    |        |  |
| 13 | Medical Care Aid           | 133 (1.8)   | 299 (3.1)   |        | 44.8   | 39.8    |        |  |
| 14 | Private health insurance   |             |             | 0.066  | 0.001§ | <0.001§ | <0.001 |  |
| 15 |                            |             |             |        |        |         |        |  |
| 16 | Non-holder                 | 2258 (30.8) | 2881 (29.7) |        | 99.3   | 35.1    |        |  |
| 17 | Holder                     | 5079 (69.2) | 6811 (70.3) |        | 77.5   | 27.7    |        |  |
| 18 | Survey year                |             |             | 0.843  | 0.695§ | 0.232§  | 0.265  |  |
| 19 |                            |             |             |        |        |         |        |  |
| 20 | 2010                       | 2592 (35.3) | 3285 (33.9) |        | 55.2   | 28.7    |        |  |
| 21 | 2011                       | 2494 (34.0) | 3308 (34.1) |        | 44.6   | 30.4    |        |  |
| 22 | 2012                       | 2251 (30.7) | 3099 (32.0) |        | 55.1   | 30.6    |        |  |
| 23 | Current smoking status     |             |             | <0.001 | 0.375§ | 0.714§  | 0.932  |  |
| 24 |                            |             |             |        |        |         |        |  |
| 25 | Non-smoker                 | 4336 (59.1) | 9148 (94.4) |        | 66.1   | 30.1    |        |  |
| 26 | Smoker                     | 3001 (40.9) | 544 (5.6)   |        | 33.3   | 26.8    |        |  |
| 27 | Alcohol consumption        |             |             | <0.001 | 0.001§ | 0.052§  | <0.001 |  |
| 28 |                            |             |             |        |        |         |        |  |
| 29 | Not excessive              | 4950 (67.5) | 8488 (87.6) |        | 21.5   | 30.3    |        |  |
| 30 | Excessive                  | 2387 (32.5) | 1204 (12.4) |        | 22.1   | 26.8    |        |  |
| 31 | Routine physical exercise  |             |             | <0.001 | 0.838§ | <0.001§ | 0.019  |  |
| 32 |                            |             |             |        |        |         |        |  |
| 33 | Physically active          | 1552 (21.2) | 1600 (16.5) |        | 55.6   | 32.9    |        |  |
| 34 | Physically inactive        | 5785 (78.8) | 8092 (83.5) |        | 44.8   | 29.3    |        |  |
| 35 | Daily sleep duration       |             |             | 0.731  | 0.150§ | <0.001§ | 0.009  |  |
| 36 |                            |             |             |        |        |         |        |  |
| 37 | Non-short                  | 4291 (58.5) | 5562 (57.4) |        | 44.2   | 27.7    |        |  |
| 38 | Short                      | 3046 (41.5) | 4130 (42.6) |        | 66.0   | 32.9    |        |  |
| 39 | Daily energy intake        |             |             | 0.001  | 0.818§ | <0.001§ | <0.001 |  |
| 40 |                            |             |             |        |        |         |        |  |
| 41 |                            |             |             |        |        |         |        |  |
| 42 |                            |             |             |        |        |         |        |  |
| 43 |                            |             |             |        |        |         |        |  |
| 44 |                            |             |             |        |        |         |        |  |
| 45 |                            |             |             |        |        |         |        |  |
| 46 |                            |             |             |        |        |         |        |  |
| 47 |                            |             |             |        |        |         |        |  |

|                        |             |             |        |         |                |
|------------------------|-------------|-------------|--------|---------|----------------|
| Not moderate           | 5859 (79.9) | 8116 (83.7) | 24.9   | 28.2    |                |
| Moderate               | 1478 (20.1) | 1576 (16.3) | 25.4   | 38.6    |                |
| Self-perceived stress  |             |             | <0.001 | 9.969§  | 0.052§ 0.285   |
| Not very high          | 7087 (96.6) | 9211 (95.0) | 25.1   | 29.7    |                |
| Very high              | 250 (3.4)   | 481 (5.0)   | 22.4   | 33.1    |                |
| Self-perceived health  |             |             | <0.001 | 5.362§  | <0.001§ 0.002  |
| Not very bad           | 7159 (97.6) | 9252 (95.5) | 25.2   | 29.3    |                |
| Very bad               | 178 (2.4)   | 440 (4.5)   | 24.2   | 42.5    |                |
| Hypertension           |             |             | <0.001 | 0.001§  | <0.001§ <0.001 |
| No                     | 5764 (78.6) | 7497 (77.4) | 22.6   | 24.4    |                |
| Yes                    | 1573 (21.4) | 2195 (22.6) | 23.6   | 48.5    |                |
| Dyslipidemia           |             |             | <0.001 | 0.001§  | <0.001§ 0.156  |
| No                     | 6859 (93.5) | 8850 (91.3) | 23.9   | 28.0    |                |
| Yes                    | 478 (6.5)   | 842 (8.7)   | 20.6   | 49.8    |                |
| Diabetes               |             |             | 0.200  | 2.858§  | <0.001§ <0.001 |
| No                     | 6661 (90.8) | 9003 (92.9) | 24.8   | 28.3    |                |
| Yes                    | 676 (9.2)   | 689 (7.1)   | 26.1   | 50.4    |                |
| Menopause              |             |             |        | <0.001§ |                |
| No                     |             | 4655 (48.0) |        | 21.6    |                |
| Yes                    |             | 5037 (52.0) |        | 37.6    |                |
| Number of participants | 7337        | 9692        | 7337   | 9692    |                |

N, number; All P-values were estimated by considering a stratified cluster sampling design.

\*Mean (standard deviation).

†P-value was estimated by using the t-test for continuous variables and  $\chi^2$  tests for categorical variables.

‡For the continuous age variable, the proportion of obesity was obtained from people aged 50-59 years to which median age for each gender belonged.

§P-value was estimated by  $\chi^2$  tests for each gender.

¶P-value was estimated from the interaction effects terms between gender and each characteristic by using the logistic analysis.

**Table S4** Adjusted associations of education and income with obesity by gender: the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010-2012, South Korea

|                                  | Women (N=9692)      |                   |
|----------------------------------|---------------------|-------------------|
|                                  | Model 1†            | Model 2‡          |
|                                  | OR (95% CI)         | OR (95% CI)       |
| <b>Main effects</b>              |                     |                   |
| Education                        |                     |                   |
| Elementary school or less (EDU1) | 1.00                | 1.00              |
| Junior high school (EDU2)        | 1.19 (0.98-1.44)    | 0.17 (0.03-1.06)  |
| Senior high school (EDU3)        | 0.90 (0.73-1.11)    | 0.21 (0.04-1.08)  |
| College or more (EDU4)           | 0.60*** (0.46-0.77) | 0.18 (0.02-1.83)  |
| Income, quartiles                |                     |                   |
| Lowest (INC1)                    | 1.00                | 1.00              |
| 2nd lowest (INC2)                | 1.00 (0.85-1.19)    | 1.77 (0.36-8.58)  |
| 3rd lowest (INC3)                | 0.91 (0.75-1.09)    | 0.89 (0.15-5.16)  |
| Highest (INC4)                   | 0.73** (0.59-0.89)  | 2.19 (0.38-12.77) |
| <b>Interaction effects</b>       |                     |                   |
| Education x Income               |                     |                   |
| EDU2 x INC2                      |                     | 0.77 (0.44-1.36)  |
| EDU2 x INC3                      |                     | 1.09 (0.59-2.04)  |
| EDU2 x INC4                      |                     | 0.49* (0.25-0.96) |
| EDU3 x INC2                      |                     | 1.78* (1.01-3.14) |
| EDU3 x INC3                      |                     | 1.44 (0.78-2.66)  |
| EDU3 x INC4                      |                     | 1.35 (0.73-2.51)  |
| EDU4 x INC2                      |                     | 1.34 (0.58-3.10)  |
| EDU4 x INC3                      |                     | 0.96 (0.41-2.26)  |
| EDU4 x INC4                      |                     | 0.73 (0.30-1.82)  |
| Hosmer-Lemeshow test, p Value    | 0.479               | 0.374             |

N, number; OR, odds ratio; CI, confidence interval; All models were adjusted for age, marital status, residential area, occupation, housing status, universal health insurance, private health insurance, survey year, smoking, alcohol consumption, routine physical exercise, daily sleep duration, daily energy intake, self-perceived stress, self-perceived health, hypertension, dyslipidemia, diabetes, and menopausal status; All estimates were obtained by considering a stratified cluster sampling design.

\* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

†Models 1 included only main effects terms for all variables.

‡Models 2 included both main effects terms and two-way interaction effects terms for all variables.



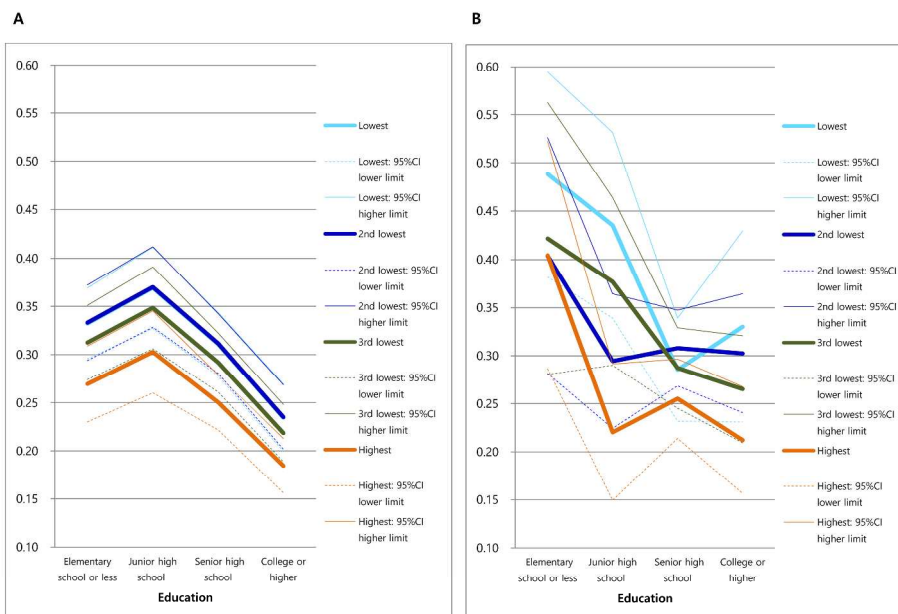


Figure S1 Predicted probabilities of being obese (and their 95% confidence intervals) by education for each income level in women in a model with only main effects (A) and a model with both main and interaction effects (B): the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010–2012, South Korea

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## STROBE Statement—checklist of items that should be included in reports of observational studies

|                              | Item No | Recommendation  |
|------------------------------|---------|---|
| <b>Title and abstract</b>    | 1       | <p>(a) Indicate the study's design with a commonly used term in the title or the abstract<br/>→ We indicated it in the title and the abstract (page 1 and 3).</p> <p>(b) Provide in the abstract an informative and balanced summary of what was done and what was found<br/>→ We provided them in the abstract (pages 3-4).</p>  |
| <b>Introduction</b>          |         |   |
| Background/rationale         | 2       | <p>Explain the scientific background and rationale for the investigation being reported<br/>→ We explained them in the introduction (pages 6-7).</p>  |
| Objectives                   | 3       | <p>State specific objectives, including any prespecified hypotheses<br/>→ We stated them in the introduction (pages 6-7)</p>  |
| <b>Methods</b>               |         |   |
| Study design                 | 4       | <p>Present key elements of study design early in the paper<br/>→ We presented them in the measures and variables section of the materials and methods (pages 8-9).</p>  |
| Setting                      | 5       | <p>Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection<br/>→ We described them in the data source and study sample sections of the materials and methods (pages 7-8).</p>   |
| Participants                 | 6       | <p>(a) <i>Cohort study</i>—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up<br/><i>Case-control study</i>—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls<br/><b><i>Cross-sectional study</i></b>—Give the eligibility criteria, and the sources and methods of selection of participants<br/>→ We presented them in the data source and study sample sections of the materials and methods (pages 7-8).</p> <p>(b) <i>Cohort study</i>—For matched studies, give matching criteria and number of exposed and unexposed<br/><i>Case-control study</i>—For matched studies, give matching criteria and the number of controls per case<br/>→ N/A</p> |
| Variables                    | 7       | <p>Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable<br/>→ We clearly defined them in the measures and variables section of the materials and methods (pages 8-9).</p>   |
| Data sources/<br>measurement | 8*      | <p>For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group.<br/>→ We indicated them in the materials and methods (pages 7-11).</p>   |
| Bias                         | 9       | <p>Describe any efforts to address potential sources of bias</p>  |

|                        |     |   |
|------------------------|-----|---|
|                        |     | → We described them in the strengths and limitations section of the discussion (page 29).   |
| Study size             | 10  | Explain how the study size was arrived at<br>→ We explained the study size in the data source and study sample section of the materials and methods (pages 7-8).  |
| Quantitative variables | 11  | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why<br>→ We explained quantitative variables' handling in the measures and variables section of the materials and methods (pages 8-9).   |
| Statistical methods    | 12  | (a) Describe all statistical methods, including those used to control for confounding<br>→ We described statistical methods in the analytic procedures section of the materials and methods (pages 9-11).<br>(b) Describe any methods used to examine subgroups and interactions<br>→ We described statistical methods in the analytic procedures section of the materials and methods (pages 9-11).<br>(c) Explain how missing data were addressed<br>→ N/A<br>(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed<br><i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed<br><b><i>Cross-sectional study</i></b> —If applicable, describe analytical methods taking account of sampling strategy<br>→ We described them in the analytic procedures section of the materials and methods (pages 9-11).<br>(e) Describe any sensitivity analyses<br>→ N/A |
| <b>Results</b>         |     |   |
| Participants           | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed<br>→ We reported them in the data source and study sample section of the materials and methods and in the table (pages 7-8, 12-15).<br>(b) Give reasons for non-participation at each stage<br>→ N/A<br>(c) Consider use of a flow diagram<br>→ N/A   |
| Descriptive data       | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders<br>→ We described them in the data source and study sample section of the materials and methods and in the table (pages 7-8, 12-15).<br>(b) Indicate number of participants with missing data for each variable of interest<br>→ N/A<br>(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)<br>→ N/A  |
| Outcome data           | 15* | <i>Cohort study</i> —Report numbers of outcome events or summary measures over time<br><i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure   |

|                          |    |  |
|--------------------------|----|--|
|                          |    | <b><u>Cross-sectional study</u></b> —Report numbers of outcome events or summary measures<br>→ We reported them in the table (pages 12-15; Table 1).   |
| Main results             | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included<br>→ We indicated them in the results and the table (pages 16-22, Table 2)  |
|                          |    | (b) Report category boundaries when continuous variables were categorized<br>→ We reported them in the measures and variables section of the materials and methods (pages 8-9).  |
|                          |    | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period<br>→ N/A  |
| Other analyses           | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses<br>→ N/A  |
| <b>Discussion</b>        |    |  |
| Key results              | 18 | Summarise key results with reference to study objectives<br>→ We indicated them in the comparison to previous studies section of the discussion (pages 22-23).   |
| Limitations              | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias<br>→ We discussed them in the strengths and limitations section of the discussion (page 29).                                  |
| Interpretation           | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence<br>→ We discussed them in the discussion (pages 22-30).   |
| Generalisability         | 21 | Discuss the generalisability (external validity) of the study results<br>→ We discussed it in the public health implications section of the discussion and in the conclusion (pages 29-30).  |
| <b>Other information</b> |    |  |
| Funding                  | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based<br>→ This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. |

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).