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

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ABSTRACT

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

Design A cross-sectional study. Education and income levels were chosen as socioeconomic status indicators. Sociodemographics, lifestyles and medical conditions were used as covariates in multivariable logistic regression models. Adjusted ORs and predicted probabilities of being obese were computed and adjusted for a complex survey design.

Setting Data were obtained from the Fifth Korea National Health and Nutrition Examination Survey (2010–2012).

Participants The sample included 7337 male and 9908 female participants aged ≥19 years.

Outcome measure Obesity was defined as body mass index of ≥25, according to a guideline for Asians.

Results In models with no interaction-effect terms of independent variables, education was significantly associated with obesity in both men and women, but income was significant only in women. However, in models with the interaction-effect terms, education was significant only in women, but income was significant only in men. The interaction effect between income and education was significant in men but not in women. Participants having the highest predicted probability of being obese over educational and income levels differed between the two types of models, and between men and women. A prediction using the models with the interaction-effect terms demonstrated that for all men, the highest level of formal education was associated with an increase in their probability of being obese by as much as 26%.

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

Strengths and limitations of this study

- The study included a nationally representative sample of South Korean adults.
- The study is the first to investigate the associations of education and income with obesity while considering both the main-effect terms of all independent variables and their interaction-effect terms.
- The study compared the predicted probabilities of being obese among various sets of education and income levels for each gender.
- The causal inferences could not be examined due to the cross-sectional design.

INTRODUCTION

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

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

Attempting to fill the gap between previous findings and the unanswered questions, this study chose education and income levels as socioeconomic status indicators because they complement each other: educational level is established in early adulthood and tends to remain unchanged later in life, while income level may change throughout adult life. In particular, this study used data from South Korea, which has industrialised rapidly and is now categorised as one of the 10 largest advanced economies in the world.[8] Nevertheless, South Korea is still noted for pronounced gender inequality almost everywhere, especially in the labour markets.[9 10]

This study considered two models for each gender: one included only the main-effect terms of all independent variables, and the other included the two-way interaction-effect terms between the independent variables, as well as their main-effect terms. Considering the complex survey design, this study used multivariable logistic regression analyses to compute the ORs of obesity and to predict the probability that a man or woman would be obese if he or she had a particular set of education and income levels.

MATERIALS AND METHODS

Data source and study sample

This study was based on the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V), 2010–2012, which used a stratified multistage clustered probability sampling design to collect data on the non-institutionalised, civilian population of South Korea on behalf of the Korea Centres for Disease Control and Prevention.[11] This survey was composed of a health interview and a nutrition survey conducted at the participants' homes, as well a physical examination conducted by physicians at designated examination centres. Detailed information about the survey design and characteristics is available at the KNHANES website.[11]

From KNHANES V, this study accessed data from a pool of 25 534 individuals (8958 in 2010, 8518 in 2011, and 8058 in 2012). Of this group, 24 173 had participated in the interviews and 18 571 individuals aged ≥19 years underwent physical examinations. A total of 17 245 (92.9%) participants (7337 men, 9908 women) were included in this study because they had the required information in their files. The ethical review board of the educational institution where the research was conducted approved this study.

Measures and variables

The obesity status of each participant was determined anthropometrically using data from the physical examination. Height was measured using a portable stadiometer, and body weight was measured using a calibrated balance-beam scale and the body mass index (BMI) was calculated from these height and weight measurements. According to the guidelines proposed by the WHO indicating that Asians have a lower average BMI,[12] this study defined general obesity as a BMI of at least 25. Also, because the percentage of participants with BMI <18.5 in the sample was very small (4.5%, 781 participants), we combined participants with BMI <18.5 and those with BMI between 18.5 and 25 into a single group. Therefore, a dichotomous outcome variable was constructed with a value of 1 (obesity, BMI ≥25) and 0 (non-obesity, BMI <25).[13–15]

Levels of education and income were chosen as socioeconomic status indicators. Education was defined as the highest level of formal education completed as of the date of the interview. This study categorised education into four levels: elementary school or less, junior high school, senior high school, and college or more. For income, this study used an equivalised monthly household income calculation ([monthly overall household income] [household size]$^{-0.5}$) and divided the participants into four quartiles.

Nine sociodemographic characteristics, including gender, were incorporated as covariates. Age was treated as a continuous variable, and marital status was categorised into married, formerly married and never married. Residential area was divided into metropolitan urban area, non-metropolitan urban area and rural area. Occupation was grouped into unemployed, office worker, and manual worker. Housing status was coded in terms of whether a participant was a renter or a home owner. Participants were categorised according to whether they were enrolled in National Health Insurance or Medical Care Aid for regular or low-income individuals, respectively, with regard to the universal health insurance programme. Participants with private health insurance were also noted. Survey year was added to control for any fixed time effect.

This study also incorporated ten characteristics about lifestyle and medical conditions. Participants were grouped in terms of the following categories: (1) smoking, (2) excessive alcohol consumption (at high risk due to drinking according to the gender-specific guidelines of the WHO),[16] (3) routinely exercising (physical activity as defined as the participation in moderate or vigorous exercise for a respective frequency and duration),[17] (4) daily sleep duration (sleeping <7 hour per day was defined as sleeping for a short duration),[18] (5) daily energy intake (moderate energy intake was defined as total energy intake within 1.25×of participants' estimated daily energy requirement),[19] (6) self-perceived stress, (7) self-perceived health, (8) hypertension, (9) dyslipidaemia and (10) diabetes. The presence of the last three chronic diseases was determined by a prior physician diagnosis at the pre-surgery interview.

Analytic procedures

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

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

Fifth, this study estimated the adjusted ORs of obesity and their 95% CIs after fully adjusting for covariates. Two models were considered for each gender: model 1 included only the main-effect term of every variable, and model 2 included the main-effect terms for each variable as well the two-way interaction-effect terms between the variables. For the two-way interaction-effect terms between the variables, we included interaction-effect terms between each pair of independent variables including income, education and nine sociodemographic covariates. We considered not only the interaction-effect terms between education and income, but also the interaction-effect terms of each of the other independent variables. In order to identify a purer interaction-effect between education and income in relation to obesity, we needed to control for other possible variables that could influence obesity including (1) main effects of each independent variable, (2) interaction-effect terms between education and each of the nine sociodemographic covariates, (3) interaction-effect terms between income and each of the nine sociodemographic covariates and (4) interaction-effect terms between each two of all nine sociodemographic covariates. In addition, the reasons why we considered the two-way interaction-effect terms between the variables, rather than the three-way or greater interaction-effect terms, were: (1) as we included three-way or greater interaction-effect terms, we had more difficulty having a sufficient number of observations for the analyses in combined categories of independent variables associated with the interactions, and (2) two-way interactions were sufficient to emphasise the importance of gender-specific interactions between education and income in relation to obesity.

Finally, to assess the association of each level of a socioeconomic status indicator with obesity and to compare these associations across categories for both socioeco nomic status indicators, this study predicted the probability of a participant being obese (and its 95% CIs) if he or she had a particular set of education and income levels. These probabilities, which were calculated by gender, denote the average of all participants' probabilities if each participant belonged to a particular set of education and income levels, while maintaining participant characteristics for the other variables constant.

All analyses and tests were conducted considering the sampling design of the survey. However, for convenience, the descriptive statistics are shown as unweighted. P values <0.05 were considered statistically significance. The SAS V.9.2 software (SAS Institute, Cary, NC, USA) and STATA V.12 software (StataCorp, College Station, TX, USA) were used to perform all statistical analyses.

RESULTS

Descriptive statistics

The rate of obesity was significantly higher in men (35.0%) than in women (29.7%), as indicated by the significantly higher BMI in men than in women (table 1). All characteristics differed significantly by gender except for residential area, housing status, enrolment in a private health insurance plan, survey year, daily sleep duration, and diabetes status.

Characteristics associated with obesity and gender differences

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

Table 1 Sample characteristics and their associations with obesity by gender: the KNHANES V, 2010–2012, South Korea

	Distribution, N (%)			Obesity, %		
	Men	Women	P value*	Men	Women	P value†
BMI (kg/m^2)‡	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	
Housing status			0.158	0.945¶	0.843¶	0.838
Home owner	5606 (76.4)	7280 (73.5)		35.1	29.5	
Renter	1731 (23.6)	2628 (26.5)		34.6	30.1	
Universal health insurance			<0.001	0.020¶	0.004¶	<0.001
National Health Insurance	7204 (98.2)	9609 (97.0)		35.2	29.4	
Medical Care Aid	133 (1.8)	299 (3.0)		24.8	39.8	
Private health insurance			0.181	<0.001¶	<0.001¶	<0.001
Non-holder	2258 (30.8)	2898 (29.3)		29.3	34.9	
Holder	5079 (69.2)	7010 (70.7)		37.5	27.5	
Survey year			0.831	0.695¶	0.133¶	0.162
2010	2592 (35.3)	3364 (34.0)		35.2	28.3	
2011	2494 (34.0)	3380 (34.1)		34.6	30.4	
2012	2251 (30.7)	3164 (31.9)		35.1	30.4	
Current smoking status			<0.001	0.375¶	0.936¶	0.729
Non-smoker	4336 (59.1)	9359 (94.5)		36.1	29.8	
Smoker	3001 (40.9)	549 (5.5)		33.3	27.1	
Alcohol consumption			<0.001	<0.001¶	0.064¶	<0.001
Not excessive	4950 (67.5)	8689 (87.7)		31.5	30.1	
Excessive	2387 (32.5)	1219 (12.3)		42.1	26.7	

Continued

Table 1 Continued

	Distribution, N (%)			Obesity, %		
	Men	Women	P value*	Men	Women	P value†
Routine physical exercise			<0.001	0.838¶	<0.001¶	0.012
Physically active	1552 (21.2)	1620 (16.4)		35.6	32.8	
Physically inactive	5785 (78.8)	8288 (83.6)		34.8	29.1	
Daily sleep duration			0.992	0.150¶	<0.001¶	0.007
Non-short	4291 (58.5)	5717 (57.7)		34.2	27.4	
Short	3046 (41.5)	4191 (42.3)		36.0	32.8	
Daily energy intake			<0.001	0.818¶	<0.001¶	<0.001
Not moderate	5859 (79.9)	8306 (83.8)		34.9	28.0	
Moderate	1478 (20.1)	1602 (16.2)		35.4	38.5	
Self-perceived stress			<0.001	0.969¶	0.031¶	0.236
Not very high	7087 (96.6)	9421 (95.1)		35.1	29.5	
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	
Dyslipidaemia			<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	

*P value was estimated by using the *t*-test for continuous variables and χ^2 tests for categorical variables.
†P value was estimated from the interaction-effects terms between gender and each characteristic by using the logistic analysis.
‡Mean (SD).
§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 χ^2 tests for each gender.
All P values were estimated by considering a stratified cluster sampling design.
BMI, body mass index; KNHANES V, Fifth Korea National Health and Nutrition Examination Survey; N, number

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

Adjusted associations of obesity with education and income

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

Table 2 Adjusted associations of education and income with obesity by gender: the 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)
Main effects								
Education								
Elementary school or less (EDU1)	1.00		1.00		1.00		1.00	
Junior high school (EDU2)	1.41**	(1.10 to 1.82)	0.61	(0.06 to 6.56)	1.19	(0.98 to 1.44)	0.16*	(0.03 to 0.89)
Senior high school (EDU3)	1.27*	(1.03 to 1.58)	0.57	(0.08 to 4.25)	0.89	(0.72 to 1.09)	0.13**	(0.03 to 0.58)
College or more (EDU4)	1.41**	(1.12 to 1.77)	1.45	(0.16 to 13.04)	0.59***	(0.46 to 0.75)	0.13*	(0.02 to 0.89)
Income, quartiles								
Lowest (INC1)	1.00		1.00		1.00		1.00	
2nd lowest (INC2)	1.13	(0.91 to 1.39)	0.11*	(0.02 to 0.64)	0.99	(0.84 to 1.16)	1.13	(0.26 to 4.98)
3rd lowest (INC3)	1.01	(0.81 to 1.28)	0.18	(0.03 to 1.11)	0.93	(0.77 to 1.11)	1.16	(0.22 to 6.20)
Highest (INC4)	1.10	(0.87 to 1.39)	0.05**	(0.01 to 0.32)	0.73**	(0.60 to 0.89)	1.58	(0.30 to 8.38)
Interaction effects								
Education×Income								
EDU2×INC2			1.91	(0.91 to 4.04)			0.77	(0.44 to 1.33)
EDU2×INC3			1.88	(0.81 to 4.34)			1.11	(0.60 to 2.06)
EDU2×INC4			1.72	(0.65 to 4.59)			0.51	(0.26 to 1.01)
EDU3×INC2			2.30*	(1.17 to 4.52)			1.58	(0.90 to 2.75)
EDU3×INC3			2.17*	(1.05 to 4.47)			1.34	(0.73 to 2.47)
EDU3×INC4			1.52	(0.67 to 3.44)			1.23	(0.67 to 2.24)
EDU4×INC2			2.74*	(1.14 to 6.56)			1.08	(0.49 to 2.39)
EDU4×INC3			3.00*	(1.27 to 7.12)			0.87	(0.38 to 2.00)
EDU4×INC4			2.65*	(1.04 to 6.78)			0.66	(0.27 to 1.58)
Hosmer-Lemeshow test, P value	0.967		0.530		0.304		0.471	

All estimates were obtained by considering a stratified cluster sampling design. 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, dyslipidaemia, and diabetes.

*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.

KNHANES V, Fifth Korea National Health and Nutrition Examination Survey; N, number.

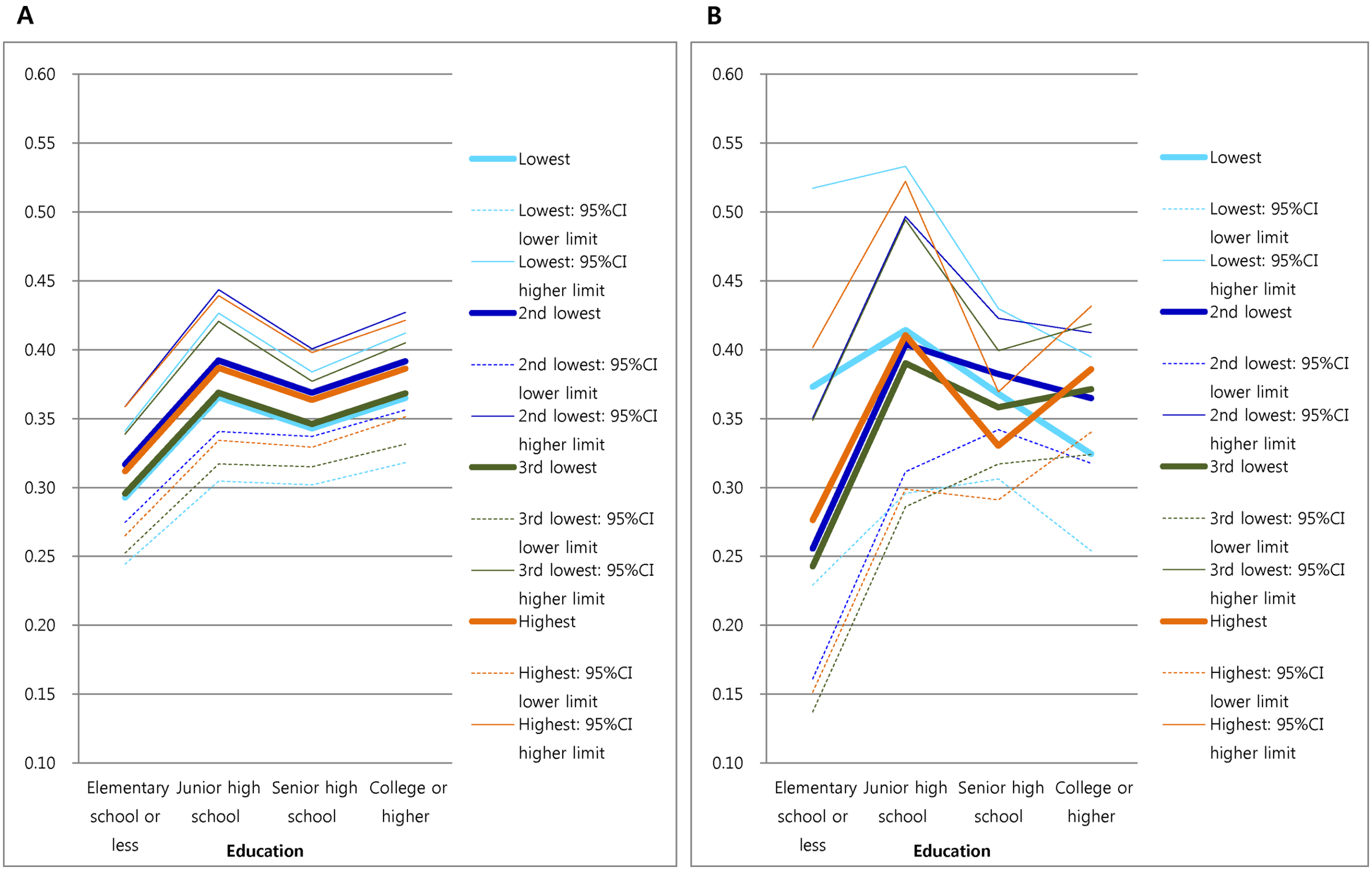

Figure 1 Predicted probabilities of being obese (and their 95% CIs) by education for each income level in men in a model with only main effects (A) and a model with both main and interaction effects (B): the KNHANES V, 2010–2012, South Korea.

Among women, according to model 1, the OR was 0.59 (95% CI 0.46 to 0.75) in participants who had at least a college education compared with those who did not go beyond elementary school, and 0.73 (95% CI 0.60 to 0.89) among those with incomes in the highest quartile compared with those with incomes in the lowest quartile. In contrast, according to model 2, the OR was 0.13 (95% CI 0.02 to 0.89) among participants with at least a college education compared with participants who did not go beyond elementary school. Income alone was not significant. In terms of an interaction effect, one combination of educational and income levels was marginally significant relative to the reference combination (P=0.053).

Predicted probability of being obese

The predicted probabilities for a participant to be obese if he or she had a particular set of education and income levels were obtained from the model with only the main-effect term of each independent variable (model 1) and from the model with both the main-effect term of each independent variable and the two-way interaction-effect terms between independent variables (model 2); these results are displayed graphically in figures 1 and 2 for men and women, respectively.

According to figures 1 and 2, the predicted probabilities of being obese differed greatly between models 1 and 2 for each gender. Whether for men or for women, the pattern of the changes in the predicted probability for each income level was uniform across educational levels in model 1 (the left panel in each figure), suggesting that the income differences in obesity are constant towards higher education. However, according to model 2 for each gender (the right panel in each figure), the pattern became very different from that in model 1 for each gender and showed clear gender differences. For example, for men, the income difference in obesity was the largest in participants who did not go beyond elementary school (0.130) and the smallest in junior high school graduates (0.024), whereas for women, the income difference in obesity was the largest in junior high school graduates (0.199), the second largest in participants who had at least a college education (0.126) and the smallest in senior high school graduates (0.052). This suggests cautiously that unlike in women, the income differences in obesity decreases towards higher education in men.

Meanwhile, with respect to the education difference in obesity, it was the largest in participants who had income in the second lowest quartile (0.148), the second largest in those with income in the third lowest quartile (0.147) and the smallest in participants who had income in the lowest quartile (0.090); but for women, it was the largest in participants who had income in the highest quartile

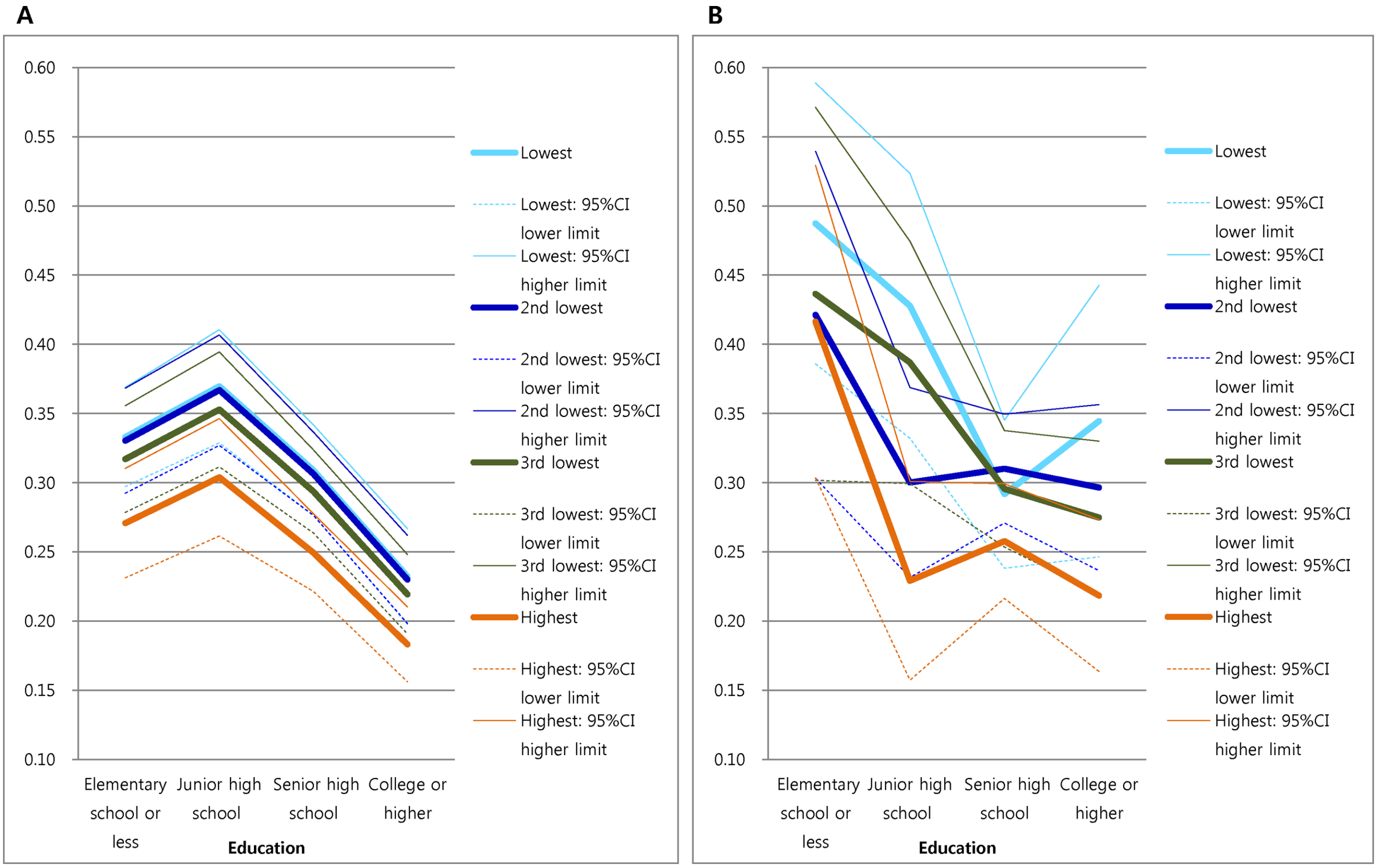

Figure 2 Predicted probabilities of being obese (and their 95% CIs) by education for each income level in women in a model with only main effects (A) and a model with both main and interaction effects (B): the KNHANES V, 2010–2012, South Korea.

(0.198), the second largest in participants who had income in the lowest quartile (0.196) and the smallest in those with income in the second lowest quartile (0.125). This suggests cautiously that the education differences in obesity show an inverse U-shape with higher income in men, in a sharp contrast with women having a U-shape.

The findings in men can be summarised as follows: (1) Although men in two income categories (the second lowest quartile and the lowest quartile) had the highest and the lowest predicted probabilities across all educational levels in model 1, respectively, no income level had these distinctions with respect to all educational levels in model 2. (2) The education–income group with the highest predicted probability according to models 1 and 2 differed: it was junior high school graduates with incomes in the second lowest quartile in model 1 (predicted probability=0.392), but it was junior high school graduates with incomes in the lowest quartile in model 2 (predicted probability=0.414). (3) The education–income group with the lowest predicted probability also differed between models 1 and 2: it was participants who did not go beyond elementary school and who had incomes in the lowest quartile in model 1 (predicted probability=0.292), but it was those did not go beyond elementary school and who had incomes in third lowest quartile in model 2 (predicted probability=0.243). (4) The gradient (or range) between the highest and lowest predicted probabilities was 0.099 in model 1 but 0.172 in model 2.

Likewise, the findings in women can be summarised as follows: (1) Although women in two income levels (the lowest quartile and the highest quartile) had the highest and the lowest predicted probabilities across all educational levels in model 1 respectively, no income level had these distinctions in model 2. (2) The education–income group with the highest predicted probability differed between models 1 and 2: it was junior high school graduates with incomes in the lowest quartile in model 1 (predicted probability=0.370), but it was participants who did not go beyond elementary school and who had incomes in the lowest quartile in model 2 (predicted probability=0.487). (3) The education–income group with the lowest predicted probability was the same in models 1 and 2: it was those with at least a college education with incomes in the highest quartile in model 1 (predicted probability=0.183) and model 2 (predicted probability=0.218). (4) The gradient in the predicted probability was 0.187 in model 1 and 0.269 in model 2.

DISCUSSION

Comparison to previous studies

Although socioeconomic status has often been shown to be a significant predictor of obesity, previous studies on the relationship between socioeconomic status and obesity focused on the main-effect terms of independent variables, rather than both the main-effect terms of the variables and their interaction-effect terms.[1–3]

Under this study limitation of including only the main-effect terms of independent variables, the literature has shown various inconsistencies regarding the relationship between a socioeconomic status indicator and obesity in either gender or between genders. The results of the previous studies were inconsistent mainly according to whether the relationship between the socioeconomic status indicator and obesity was found to be positive, negative or insignificant for each gender. As for education, for example, the relationship between education and obesity was found to be: positive in both men and women in Finland[20] and India[21]; positive in men but negative in women in the USA[22] and Iran[23]; positive in men but insignificant in women in the USA[24] and Peru[25]; insignificant in men but negative in women in the USA[26] and Italy[27]; and insignificant in both men and women in the Netherlands[28] and Finland.[29]

As for income, the relationship between income and obesity was found to be the following: positive in both men and women in the USA[30] and Sri Lanka[31]; positive in men but insignificant in women in the USA[32] and South Korea[33]; insignificant in men but negative in women in Singapore[34] and Canada[35]; and insignificant in both men and women in the USA,[26] Canada,[35] Greece[36] and China.[37]

In particular, many studies indicated that socioeconomic status and obesity are negatively correlated in both men and women in developed countries,[1 2] being consistent for both education and income, as shown in France[4] and the USA[5] for education and in Australia[6] and the USA[7] for income.

Considering the interaction-effect terms between independent variables, however, the results of our study suggest that in certain developed countries like South Korea, education and income may not have negative associations with obesity in either men or women and they may have somewhat complex relationships with obesity because of the interaction effects between independent variables.

This suggestion is depicted clearly in both table 2 and figures 1, 2 models including the main-effect terms of all independent variables considered in this study and their two-way interaction-effect terms in table 2, the main-effect of income as well as the interaction-effect term between education and income was significant in men, but only the main-effect term of education was significant in women. It seems that in men income plays a role in its association with obesity on its own as well as through its interaction with education, whereas education plays a role only through its interaction with income; in women, however, education plays a role in its association with obesity on its own, despite no role for income.

Further, complex relationships between each of the education and income levels with obesity are suggested in figures 1 and 2. In models including main-effect terms of all independent variables and their two-way interaction-effect terms (as shown in the right panels denoted as B in figures 1 and 2), the differences in the predicted probability of being obese between income levels at a certain education level varied markedly between education levels, and their gender differences were very evident. Furthermore, people with a particular set of education and income levels showing the highest (or lowest) risk of obesity, in terms of the predicted probability of being obese, changed after including the two-way interaction-effect terms for each gender.

Therefore, the results of our study may caution researchers considering only the main-effect terms in studies of the associations of education and income with obesity to be very careful about interpreting their results. The reasons are as follows: (1) studies considering only the main-effect terms may come to incorrect conclusions about the roles of education and income; (2) those studies may fail to explore how the income differences in obesity at an education level are different from those at another education level (or how the education differences in obesity at an income level are different from those at another income level); and (3) those studies may result in the incorrect identification of the education–income group having the highest (or lowest) risk of obesity.

In addition, according to the results of our study of South Korea, the aforementioned well-known negative association between socioeconomic status and obesity in developed countries should be re-examined using models incorporating interaction-effect terms among various characteristics. Similar results were obtained with regard to abdominal obesity as those reported here for general obesity (these results are available on request).

Plausible mechanisms

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

To examine this, we provided the online supplementary tables 1 and 2, which show the distributions of sample characteristics by education and income for men and women, respectively. For men, as shown in the right panel of figure 1, the highest predicted probability of being obese was shown in junior high school graduates with incomes in the lowest quartile (predicted probability=0.414), whereas the lowest predicted probability in participants those who did not go beyond elementary school and who had incomes in third lowest quartile (predicted probability=0.243). Relative to the education–income group showing the lowest predicted probability of being obese, the group showing the highest predicted probability tended to have more than twice as high as proportion in participants who were formerly married, participants who were never-married, residents in non-metro urban areas, manual workers, participants surveyed in 2010, current smokers, participants who had energy intake at a moderate level, participants who reported that their health was very bad, participants having hypertension and participants having diabetes (online supplementary table 1).

Likewise, for women, as shown in the right panel of figure 2, the highest predicted probability of being obese was shown in participants who did not go beyond elementary school and who had incomes in the lowest quartile (predicted probability=0.487), whereas the lowest predicted probability in participants with at least a college education with incomes in the highest quartile (predicted probability=0.218). Compared with the education–income group showing the lowest predicted probability of being obese, the group showing the highest predicted probability tended to have more than twice as high as proportion in participant who were formerly married, residents in rural areas, participants who were unemployed, participants whose daily sleep duration were short, participants who reported that their stress was very high, participants who reported that their health was very bad, participants having hypertension, participants having dyslipidaemia and participants having diabetes (online supplementary table 2).

This comparison suggests that a participant's belonging to a particular one of different education–income groups (ie, a social position) is associated with a particular risk of obesity. A variety of studies on social position have shown that one's social position may be determined exogenously or endogenously.[38 39] An individual can be placed in a social position (or social status) within a society before or at birth. This is called ascribed status. Ascribed statuses, which differ across societies, exist in all societies. Ascribed statuses depend on genetics, gender, age, race or family characteristics. Alternately, an individual can achieve his or her social position by his or her own efforts, which is called achieved status. Achieved statuses are social position which he or she acquires after his or her birth as consequences of the exercise of knowledge, ability and skill, personal perseverance and active interactions with others. Both education and income provide examples of social position that may be either ascribed or achieved status. Meanwhile, when comparing men and women, if education is more of an ascribed status rather than an achieved status, compared with the income, then education is more likely to make a positive contribution to income in women compared with that in men. Then the role of education on obesity may overtake that of income on obesity in women compared with men. Meanwhile, income in combination with education rather than education alone may influence the risk of obesity in men. It seems definite that further research is necessary to evaluate the relationship between social position and obesity.

Second, with regard to its association with obesity, why does education sometimes interact with income and why does the interaction differ by gender? This study believes that two different factors may be involved in this issue. More education may discourage obesity insofar as it promotes a more efficient use of health-related services and products[40 41] and an enhanced sense of control and empowerment.[42 43] In addition, and less directly, more education may contribute to a higher income, which may discourage obesity by increasing access to higher quality food and better medical care.[40 41] However, in a subgroup of people (eg, men with certain sociocultural characteristics), a higher income may be positively associated with obesity even though more education leads to higher income. Thus, more education and a higher income may lead to a higher likelihood of being obese among this subgroup of people. Meanwhile, it is interesting to note that gender may modify the effects of education and income on one's health. Previous research has suggested that gender,[44] race,[45] place[45 46] and their intersections[47 48] alter the effects of education and income on health. A recent study compared race–gender groups to examine the effects of baseline education and income on sustained health problems in five domains (depressive symptoms, insomnia, physical inactivity, BMI, and self-rated health) using the Health and Retirement Study in the USA.[47] This study found that the interaction of race and gender changed the protective effects of social determinants on sustained health problems such as insomnia, physical inactivity and BMI. Another study showed that gender modifies the effects of education and income on psychosocial well-being of patients with chronic conditions.[44]

It is generally known that women with a high level of education tend to be more worried about weight control than men with the same level of education.[49] This may be because obese women may be more penalised with regard to employment opportunities,[50] wage equality[51] and finding marriage partners than obese men.[52] On the other hand, even men with a high income tend to feel more comfortable being overweight than do women in the same income group.[53] This can be explained in part by the notion of habitus and Bourdieu's theory, which states that the body has a symbolic value in size and shape for people, but that valuations of the body differ by gender.[54 55]

Even in a developed society such as South Korea, men have more political and economic influence and are the primary wage earners for families, and most jobs tend to be awarded first to men. Gender differences in body image are also pronounced in South Korea: according to an international study of body image and weight control in young, educated adults, the age-adjusted prevalence of feeling overweight was the second lowest in Korean men (14%) compared with that in men in the other 22 countries, but the prevalence of seeing oneself as overweight was the highest in Korean women (77%).[53] Thus, local culture and norms put greater pressure on women than on men to lose weight, as indicated in previous studies.[53 56 57]

As a third question to be raised from the results of this study, after including the interaction-effect terms in this study, why did the predicted probabilities of being obese follow erratic rather than uniform patterns for both education and income levels, and why were there gender differences in this regard? One reason for the erratic patterns in the predicted probabilities might be that education or income may interact with some other covariate(s). For example, the association between obesity and income may be influenced by stress level in men[58] and health behaviours caused by a high level of stress, such as smoking cigarettes and drinking alcohol, thereby contributing to the positive association between socioeconomic status and obesity in men.[59 60] Meanwhile, previous studies investigated the relationship among contextual factors (eg, gender, race, class and place), psychosocial factors and obesity factors (eg, obesity and BMI).[61–65] Using data from the Health and Retirement Study in the USA, a study showed that the association between sustained health problems such as depression and obesity are not universal across race and gender groups.[62] This suggests that culture connected to race and gender may influence cognitive and emotional elements that are essential for the perception of obesity and associated weight management behaviours.[66]

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

There are three potential reasons for the gender differences in the predicted probabilities of being obese for both education and income levels. First, these gender differences partly derive from gender differences in the covariates that interact with education or income. For example, in the present study, educational level showed significant interaction effects with residential area, excessive alcohol consumption, self-perceived stress, self-per ceived health and survey year in men, whereas women's educational level interacted significantly with age, marital status, housing status, hypertension and diabetes (results not shown). Second, although covariates interact with education or income in both men and women, the magnitude of the interactions between the covariate categories and levels of education or income might differ by gender. Previous studies showed that, unlike in women, increased income does not result in an equivalent adaptation to healthier behaviours in men.[32] Finally, there may be gender differences in the reverse causation between education or income and obesity. For example, in certain patriarchal societies, girls with a health problem may be less likely to have a high level of education than their male counterparts.[67]

An extended study of women

Unlike men, because women may be subject to the effects of pregnancy and breastfeeding, it would be worthwhile to take women-specific characteristics into consideration and construct a new sample of women, and compare their results with the results obtained from the men's sample. Therefore, we extended our study with a special consideration of women as follows: (1) to construct a new sample of women, we excluded pregnant women (n=120) or breast-feeding women (n=188) from the analysis, because their bodyweight can be affected by childbearing; (2) we further categorised women according to their menopausal status and included that status as an additional covariate (where not-menopausal was the reference group), because menopause may be associated with obesity[68]; with the new sample of 9692 women, we conducted all the analytic procedures included in the materials and methods chapter; and, finally, we provided the results in the online supplementary tables 3 and 4 and the online supplementary figure 1.

According to the results, the differences in the proportion and the obesity rate among all characteristics were very similar between the prior sample of women and the new sample (table 1 and online supplementary table 3). Regarding menopausal status in the new sample, in comparison with women who were not menopausal, menopausal women were higher in their proportion (57.0% vs 48.0%) and showed a significant higher rate of obesity (37.6% vs 21.6%).

In the model with only main-effect terms (model 1), the OR of obesity was 0.60 (95% CI 0.46 to 0.77) in those with at least a college education compared with their counterparts who did not go beyond elementary school; and the OR was 0.73 (95% CI 0.59 to 0.89) among those with incomes in the highest quartile compared with those with incomes in the lowest quartile (online supplementary table 4). These results were also very similar to those obtained from the prior sample (table 2).

Meanwhile, according to the model with interaction-effect terms (model 2), neither education alone nor income alone was significant. Instead, education and income were found to interact with each other in relation to obesity, as the two combinations of educational and income levels were significant when compared with their respective reference combinations. These results are different from those obtained from the prior sample (table 2): in that sample, education alone was significant, whereas neither income alone nor any interaction-effect term between education and income was significant.

The pattern of the changes in the predicted probability of being obese for each income level across educational levels in models 1 and 2 (online supplementary figure 1) appears very similar to those obtained from the prior sample (figure 2). In details, however, the predicted probabilities of being obese changed slightly in the new sample: for example, the highest predicted probability of being obese was shown in participants who did not go beyond elementary school and who had incomes in the lowest quartile in both the prior sample and the new sample, but the predicted probability was 0.487 in the prior sample and 0.488 in the new sample.

In summary, the extended study of women suggests that whether or not the sample of women in the studies of obesity considers women-specific characteristics which may be related to obesity, these studies need to include the interaction effects of independent variables to explore precisely the associations between education and income in relation to obesity.

Public health implications

From a policy perspective, it is of interest whether as a government attempts to provide people with the highest level of education, its actions can lead to a reduction in the prevalence of obesity and the socioeconomic gradient in such prevalence. Though caution is required when making policy predictions based on findings from cross-sectional data, according to the findings of this study, the answer might be ‘no’. An enhanced governmental educational policy that enables all men to complete the highest level of formal education would reduce the gradient in the predicted probability of being obese by 53%, from 0.130 to 0.061, but would also increase the average predicted probability by 26%, from 0.287 to 0.362. Conversely, the same enhanced educational policy in women would raise the gradient in the predicted probability by 77%, from 0.071 to 0.126, but would lower the average predicted probability by 36%, from 0.440 to 0.283. This suggests that, in order to meet both goals (low prevalence of obesity and reduced gradient by socioeconomic status), educational policies should be implemented in combination with other social policies and these governmental efforts should be differentiated by gender. These results may elicit a new debate about whether educational policies should consider health consequences.[69 70] Meanwhile, some cross-country studies have shown that the determinants of health particularly the effects of social determinants are specific to countries and have emphasised the need for local studies that inform local policies and programmes.[46 71 72]

Strengths and limitations

This study analysed data from a nationally representative sample of South Korean adults, providing abundant information about anthropometric measures, sociodemographic characteristics, lifestyle behaviours and medical conditions. Using a quantified prediction, this study shows what would happen if policies to reduce obesity prevalence did not consider complex interactions among the characteristics of individuals. Above all, this study is the first to address the association of socioeconomic status with obesity while considering both the main-effect term of each independent variable and the two-way interaction-effect terms between independent variables. We believe that our research findings can be generalisable to settings other than those in South Korea because of the following: our research included a broad range of participants from a nationally representative sample of the South Korean population through the KNHANES; the nature and level of education, income and covariates can be comparable; and the definition of general obesity can be relevant to other settings or countries.

However, this study has several limitations. The cross-sectional study design precludes causal inferences about the relationship between socioeconomic status and obesity. Moreover, the data were collected by a self-report survey, which may have resulted in measurement error and recall bias. Although it is beyond the scope of this study, it would be of great interest to explore gender-specific interactions among education, income and other socioeconomic status indicators like occupation, home-ownership and marital status. Other potential covariates, such as genetics, social network, parity and parental obesity, were not included in analyses because these data were not available. Unobserved factors, such discount rate and risk aversion, may have influenced both socioeconomic status and body weight.[73 74] Finally, we also could not incorporate race and ethnicity into our analysis because the KNHANES did not include these data and, moreover, because the absolute majority of the population is of Korean ethnicity.[75 76]

CONCLUSIONS

This is the first study to investigate the association of socioeconomic status with obesity while considering both the main-effect term of each independent variable and the two-way interaction-effect terms between independent variables. This study highlights the importance of interaction effects in studies of the associations of socioeconomic status with obesity. According to the results, moving from models evaluating only main effects to models evaluating both main and interaction effects may change the association of socioeconomic status with obesity, the group with the highest likelihood of obesity, the gradient in the likelihood of obesity by socioeconomic status and gender differences in the associations of socioeconomic status with obesity. These results suggest that studies on the association between socioeconomic status and obesity should include interaction-effect terms for all characteristics and consider gender differences, and that policy efforts to reduce obesity and the resulting socioeconomic gradients should be established based on the results of those in-depth studies. Moreover, further research is needed to examine whether these findings are valid in other sociocultural settings.

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