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# The relationship between high blood glucose and socio-economic position in childhood and adulthood in Korea: findings from the Korean National Health and Nutrition Examination, 2007–09

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**Background** Unlike the older birth cohort (1943–65), the younger birth cohort (1966–79) has enjoyed much improved standards with dramatic developments in Korea. This article investigated the relationship between socio-economic position (SEP) and risk of high blood glucose, including impaired fasting glucose (IFG) and type 2 diabetes mellitus (T2D) by birth cohort.

**Methods** Of the 11 830 persons, 9792 persons aged 30–64 years participated in National Health and Nutrition Examination Surveys. We categorized four SEP groups based on education level in childhood and adulthood within two birth cohorts. High blood glucose included IFG ($n = 2594$) and T2D ($n = 738$). Odds ratio (OR) and 95% confidence interval (CI) were estimated by logistic regression.

**Results** There was a significantly higher risk of high blood glucose in the younger cohort than in the older cohort. In the younger cohort, the ORs for males of declining SEP and of stable low SEP were OR: 1.50 (95% CI 1.12–2.00) and OR: 1.45 (95% CI 1.08–1.93), respectively. After adjustments, corresponding ORs were 1.47 (95% CI 1.09–1.98) and 1.54 (95% CI 1.14–2.08), respectively. In younger women, the corresponding ORs were 1.68 (95% CI 1.17–2.41) and 1.87 (95% CI 1.30–2.69), respectively; however, obesity attenuated the former relationship. For women in the older cohort, this inverse relationship was found only among those with a stable low SEP (OR 1.31, 95% CI 1.04–1.66); no significance was found after adjustments. There was no significant inverse relationship in the older cohort for men.

**Conclusions** The relationship between lower SEP and elevated risk of high blood glucose was stronger in the younger birth cohort, and obesity attenuated this inverse relationship in women only.

**Keywords** socio-economic position, birth cohort, type 2 diabetes mellitus, impaired fasting glucose, Korea

## Introduction

A series of recent studies have consistently reported the inverse association between an elevated risk of developing type 2 diabetes mellitus (T2D) and lower socio-economic position (SEP) in adulthood.[1,2] Although most of the evidences support the stronger effect of adult SEP than childhood SEP on T2D,[3] low childhood SEP may continue to influence adult SEP as both were highly correlated.[4–6] The potential mechanism underlying the relationship between SEP and T2D is not yet fully understood.[7] The literature suggests that a complex process is involved in inverse gradients of SEP with a greater risk for unfavourable conditions, including low birthweight, depression, obesity, unhealthy diet and smoking, all of which are related to T2D.[7–10]

In most countries, the relative importance of SEP may differ substantially considering, for example, a dramatic increase of education level during the past century.[11–13] However, little is known about the differential effect of SEP on health outcomes over time.[13] Moreover, Asians are thought to have a higher susceptibility to T2D than Caucasians as they may develop it at a relatively lower degree of obesity and they appeared to have a more pronounced dysfunction in early insulin secretion.[14,15] Nevertheless, most studies exploring the association between SEP and diabetes have focused on Caucasians in developed countries. Korea has experienced rapid economic development during the past century, leading to considerably different socio-demographic characteristics between different birth cohorts.[12] Besides, a line of evidence has supported that impaired fasting glucose (IFG) alone increases the risk of coronary heart disease by 2- to 3-fold,[16] and is often associated with an unfavourable metabolic profile.[17] Therefore, we evaluated the relationship between SEP in childhood and adulthood and the prevalence of high blood glucose, including both IFG and T2D, in two birth cohorts (1943–65 and 1966–79) based on a nationally representative survey carried out during 2007–09.

## Methods

### Study population and data collection

This study is a secondary data analysis of data collected during the Korean National Health and Nutrition Examination Survey (KNHANES) conducted during 2007–2009. KNHANES is a cross-sectional survey based on stratified, multistage probability samples of Korean households, representing the civilian, non-institutionalized population. It includes a health interview, a survey of health behaviours and a nutritional and health examination following a standardized protocol. An in-depth review of KNHANES has been published elsewhere.[18] We analysed a sample of 11 830 adults aged 30–64 years who underwent fasting blood evaluations and interview survey in KNHANES from 2007 to 2009 (2150 in 2007, 4652 in 2008 and 5028 in 2009). We excluded those responses that did not include the following information: measurement of fasting glucose ($n = 935$) and the educational level achieved either in childhood (1164) or in adulthood (741). As such, the final sample for this analysis included 9792 persons with complete information on blood glucose and educational level: 4264 men and 5528 women.

### SEP

Korea has experienced substantial social changes during the past century, including colonization by Japan (1919–45), the Korean War (1950–53), post-war reconstruction (1954–64) and rapid economic development (1965 to present).[12] Considering both the historical context and the age group of participants, we categorized the study sample into two birth cohorts, 1943–65 and 1966–79, which correspond to the current age groups of 45–64 and 30–44 years old, respectively. Unlike the older birth cohort (1943–65), the younger cohort (1966–79) enjoyed much improved living standards due to the unprecedented economic development in Korea.

Among the available SEP variables that included education, occupation and income variables, we chose education as the SEP indicator as 42.9% of the female participants in this study were housewives and KNHANES has a tendency to overestimate income.[19] Moreover, several studies have demonstrated that education level may be an influential indicator in assessing socio-economic differences,[19,20] as it reflects occupation, as well as income and is related to an ability to obtain or understand health-related information in general.[21] Information regarding their fathers' education levels when participants were 14 years old was obtained retrospectively. We categorized SEP both in adulthood and childhood into groups of similar proportion according to birth cohort. Paternal education level was, thus, classified into low (less than or equal to elementary school for the younger cohort and less than elementary school for the older cohort) and high, as the paternal education level of 34.9% of the men in the older cohort was less than elementary school compared with 7.9% of men in the younger cohort. In addition, participants' education level was categorized into high (more than or equal to college graduates for the younger cohort, more than or equal to high school graduates for the older cohort) and low. To assess the relationship between a change in SEP and the risk of high blood glucose, considering the stronger effect of SEP in adulthood[3] than of SEP in childhood, participants were categorized into one of four SEP categories based on SEP in childhood and adulthood as follows: stable high (childhood high, adulthood high), improving (childhood low, adulthood high), declining (childhood high, adulthood low) and stable low (childhood low, adulthood low).

### Impaired fasting glucose and T2D

High blood glucose including IFG or T2D was confirmed if at least one of the following was satisfied: (i) elevated plasma glucose levels of $\geqslant$100 mg/dl following at least 8 h of fasting; (ii) taking medication for diabetes or treatment with insulin; and (iii) diagnosis from a doctor.

### Covariates

Participants were asked to wear a standardized gown, and their heights were measured to the nearest 0.1 cm using a stadiometer; weights were measured to the nearest 0.1 kg using a balance beam scale in order to calculate body mass index (BMI, $kg/m^2$). Waist circumference (WC) measurements were taken at the end of normal expiration to the nearest 0.1 cm, measuring from the narrowest point between the lower border of the rib cage and the iliac crest. A BMI of $\geqslant$25 $kg/m^2$ was considered overweight and abdominal obesity was defined as $\geqslant$90 cm in men and $\geqslant$85 cm in women. After at least 8 h of overnight fasting, the fasting plasma concentrations of glucose, insulin, total cholesterol, triglycerides (TG) and high-density lipoprotein (HDL) were measured enzymatically using the Hitachi 747 chemistry analyzer (Hitachi 747, Daiichi, Tokyo, Japan). Hypertriglycerides were defined as $\geqslant$200 mg/dl. Low HDL was $<$40 mg/dl in men and $<$50 mg/dl in women. Participants were grouped based on total cholesterol $<$240 or $\geqslant$240 mg/dl.

Information regarding household income and health behaviours was collected through self-administered questionnaires. Household income was categorized in terms of the poverty line: low ($<$120% of poverty line), middle (120–249% of poverty line) and high ($\geqslant$250% of poverty line). We defined the physical activity to be lasting at least 30 min on $\geqslant$5 days of the week. Smokers were categorized into current, previous and never as the reference of time at survey. Those who had drunk more than once a month were included as drinkers. Self-reported perception stress in daily life was rated on a four-point Likert scale, summing the top two responses to measure being stressful. Depression was defined if someone felt sad or despair lasting $>$2 weeks, which interfered with daily life during the last year. Suicidal ideation was defined if someone had thought about suicide or wanted to take their own life during the last year. Dietary information was obtained using a single 24-h recall method. The proportion of calories from carbohydrates ($>$70% and $\leqslant$70%) and total energy intake were selected as risk variables.

### Statistical analysis

All analyses were conducted separately by gender and birth cohort. The linear trend of health-related characteristics and prevalence of biological variables by SEP level in childhood and adulthood were assessed using the Cochran–Armitage test for trend. The effects of SEP in childhood and adulthood on the prevalence of high blood glucose were tested using logistic regression, and the results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). The linear trend tests for ORs were conducted by treating the value of each group of SEP level in adulthood and childhood (high/high = 1, high/low = 2, low/high = 3 and low/low = 4) as continuous variables in a multiple logistic regression model. Interactions for gender and for SEP in adulthood and childhood were tested before fitting the model. In addition, we treated significant covariates by gender and birth cohort as potential confounders and adjusted it. Accordingly, we set up three models by gender and birth cohort. Model 1 was adjusted for age. Model 2 was adjusted for age, physical activity, depression and suicidal ideation in common; the proportion of calories from carbohydrates, stress, TG, HDL and smoking was adjusted differently according to gender and birth cohort. Model 3 included Model 2 covariates in addition to abdominal obesity and overweight measured by BMI. All analyses were conducted using PASW 18.0 (SPSS Inc.) and statistical significance was determined at the level of 0.05.

## Results

The level of education and the blood glucose were substantially different by birth cohort both in men and women, as depicted in Table 1. In the older cohort, 72.4% of the men reported a paternal education equal to or less than elementary school compared with 41.6% in the younger cohort; for women, it was 70.6% and 39.5%, respectively. The proportion of men who were college graduates or above was much lower in the older cohort (27.7%) compared with the younger cohort (57.5%); for women, it was 11.9% and 45.1%, respectively. In addition, those who belonged to T2D were 14.7% in the older cohort and 4.0% in the younger cohort among males; for women, it was 9.4% and 2.5%, respectively. Among the older cohort, the prevalence of IFG was 43.2% in males and 28.9% in females.

Lower SEP groups, either in childhood or adulthood, exhibited a generally increasing trend of unfavourable characteristics, including lower income, depression and suicidal ideation, except for physical activity (Table 2). The prevalence of smoking or drinking was higher in the younger cohort, whereas stress was more prevalent in women in the older cohort among the lower SEP groups.

As SEP decreased, there was a decreasing likelihood of being overweight in the older cohort and abdominally obese for men in the younger cohort (Table 3).

**Table 1** Distribution of education level and blood glucose by gender and birth cohort

| Variables | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | Birth cohort 1943–65, n(%) | Birth cohort 1966–79, n(%) | P[a] | Birth cohort 1943–65, n(%) | Birth cohort 1966–79, n(%) | P[a] |
| Education level | 2215 (100.0) | 2049 (100.0) | | 2774 (100.0) | 2754 (100.0) | |
| **Paternal education** | | | | | | |
| Less than elementary (6 years) | 772 (34.9) | 162 (7.9) | <0.01 | 919 (33.1) | 201 (7.3) | <0.01 |
| <Elementary (6 years) | 831 (37.5) | 691 (33.7) | | 1041 (37.5) | 886 (32.2) | |
| Junior high (9 years) | 257 (11.6) | 467 (22.8) | | 318 (11.5) | 659 (23.9) | |
| High (12 years) | 211 (9.5) | 495 (24.2) | | 315 (11.4) | 691 (25.1) | |
| ⩾college (14 years) | 144 (6.5) | 234 (11.4) | | 181 (6.5) | 317 (11.5) | |
| **Adult education** | | | | | | |
| Less than elementary (6 years) | 56 (2.5) | 0 (0.0) | <0.01 | 245 (8.8) | 3 (1.1) | <0.01 |
| Elementary (6 years) | 389 (17.6) | 23 (1.1) | | 803 (28.9) | 28 (1.0) | |
| Junior high (9 years) | 425 (19.2) | 71 (3.5) | | 590 (21.3) | 110 (4.0) | |
| High (12 years) | 731 (33.0) | 776 (37.9) | | 804 (29.0) | 1372 (49.8) | |
| ⩾college (14 years) | 614 (27.7) | 1179 (57.5) | | 332 (11.9) | 1241 (45.1) | |
| **Blood glucose[b]** | | | | | | |
| Normal | 1258 (56.8) | 1567 (76.5) | <0.01 | 1972 (71.1) | 2401 (87.2) | <0.01 |
| Impaired fasting glucose | 631 (28.5) | 400 (19.5) | | 541 (19.5) | 284 (10.3) | |
| Diabetes mellitus | 326 (14.7) | 82 (4.0) | | 261 (9.4) | 69 (2.5) | |

[a]Tested by chi-square, significant at $P < 0.05$.
[b]IFG: elevated plasma glucose levels of ⩾100 mg/dl following at least 8 h of fasting; diabetes mellitus: (i) elevated plasma glucose levels of ⩾126 mg/dl following at least 8 h of fasting; (ii) taking medication for diabetes or treatment with insulin; or (iii) diagnosis from a doctor.

In addition, lower SEP in adulthood and childhood was associated with a significant increase in prevalence of high blood glucose for men in the younger cohort. On the contrary, there was an increasing trend of both abdominal obesity and overweight for females in the lower level SEP groups. For the women, most biological risk factors increased according to a decreased SEP and the prevalence of high blood glucose was the highest among those with a low SEP both in childhood and adulthood.

There was a significantly higher risk of high blood glucose for those with a declining and stable low SEP when compared with those with stable high SEP in the younger men and women groups; however, this relationship in women with a declining SEP disappeared after adjusting for obesity (Table 4). For men in the younger cohort, the OR for developing high blood glucose was 1.50 (95% CI 1.12–2.00) in the declining SEP group and 1.45 (95% CI 1.08–1.93) in the stable low SEP group. After adjusting for multiple covariates, including obesity, this relationship was not attenuated in either those with a declining SEP (OR: 1.47, 95% CI 1.09–1.98) or those with a stable low SEP (OR: 1.54, 95% CI 1.14–2.08). On the contrary, no significant relationship was observed between SEP and high blood glucose among men in the older cohort. For women in the younger cohort, the inverse relationship was significant among those with a declining (OR: 1.68, 95% CI 1.17–2.41) or a stable low SEP (OR: 1.87, 95% CI 1.30–2.69). After adjusting for obesity, the independent effect of a lower SEP on the risk for developing high blood glucose still remained in women with a stable low SEP (OR: 1.67, 95% CI 1.14–2.45), but not for women with a declining SEP (OR: 1.41, 95% CI 0.95–2.06). Likewise, significant increasing OR trends for the lower SEP groups also disappeared after adjusting for obesity in younger women. For women in the older cohort, the relationship between high blood glucose and SEP was significant only among those with a stable low SEP (OR: 1.31, 95% CI 1.04–1.66) in Model 1.

In the younger group, there was a similar trend of risk in men and women and no gender interaction ($P = 0.56$ for Model 1, $P = 0.84$ for Model 2 and $P = 0.68$ for Model 3). However, in the older group, we found significant gender interaction for Model 1 ($P = 0.01$) and Model 2 ($P = 0.05$), but not for Model 3 ($P = 0.39$). Besides, the results of separate analyses of IFG and T2D yielded relationships that were somewhat similar to those from the combined analysis of high blood glucose including IFG and T2D (data not shown).

**Table 2** Health-related characteristics[a,b] according to SEP (measured by educational levels) in childhood and adulthood by gender and birth cohort

| Variables | SEP level[c] in childhood and adulthood | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | | | | Women | | | | |
| | Participant (⩾14 years) | | Participant (<14 years) | | | Participant (⩾14 years) | | Participant (<14 years) | | |
| | Father (⩾6 years) | Father (<6 years) | Father (⩾6 years) | Father (<6 years) | *P* for trend | Father (⩾6 years) | Father (<6 years) | Father (⩾6 years) | Father (<6 years) | *P* for trend |
| Birth cohort 1943–65 (%) | | | | | | | | | | |
| *N* | 1050 | 295 | 393 | 477 | | 959 | 177 | 896 | 742 | |
| Income (low) | 11.8 | 15.9 | 32.1 | 37.9 | <0.01 | 12.8 | 18.4 | 33.6 | 41.5 | <0.01 |
| Physical activity | 14.1 | 13.9 | 17.3 | 19.7 | <0.01 | 14.5 | 18.6 | 19.5 | 18.6 | 0.01 |
| Smoking | 40.3 | 31.9 | 43.5 | 41.6 | 0.80 | 4.1 | 4.0 | 3.7 | 4.2 | 0.65 |
| Drinking | 74.7 | 73.9 | 74.0 | 70.6 | 0.13 | 34.7 | 32.2 | 36.5 | 30.8 | 0.29 |
| Stress | 23.1 | 24.1 | 22.7 | 24.1 | 0.78 | 25.1 | 19.9 | 29.6 | 30.5 | <0.01 |
| Depression | 10.2 | 9.5 | 12.5 | 15.9 | <0.01 | 16.0 | 16.9 | 22.2 | 23.2 | <0.01 |
| Suicidal ideation | 8.6 | 9.9 | 12.5 | 18.1 | <0.01 | 13.7 | 19.8 | 22.0 | 26.3 | <0.01 |
| Carbohydrate (>70%) | 36.7 | 38.9 | 44.5 | 50.0 | <0.01 | 50.6 | 55.6 | 68.7 | 69.6 | <0.01 |
| Birth cohort 1966–79 (%) | | | | | | | | | | |
| *N* | 526 | 208 | 670 | 645 | | 552 | 147 | 1115 | 940 | |
| Income (low) | 6.0 | 4.4 | 15.2 | 20.5 | <0.01 | 5.9 | 8.3 | 12.7 | 18.8 | <0.01 |
| Physical activity | 10.9 | 10.7 | 14.3 | 18.4 | <0.01 | 10.7 | 12.3 | 12.3 | 14.5 | 0.04 |
| Smoking | 48.5 | 38.5 | 62.5 | 58.8 | <0.01 | 2.0 | 0.7 | 7.6 | 6.4 | <0.01 |
| Drinking | 78.3 | 79.3 | 78.8 | 82.0 | 0.15 | 39.1 | 33.3 | 51.5 | 52.4 | <0.01 |
| Stress | 36.1 | 35.6 | 33.1 | 33.2 | 0.23 | 30.4 | 32.0 | 33.0 | 28.1 | 0.38 |
| Depression | 7.0 | 7.2 | 9.7 | 10.2 | 0.03 | 12.9 | 8.8 | 15.1 | 14.3 | 0.25 |
| Suicidal ideation | 7.0 | 5.3 | 11.0 | 11.6 | <0.01 | 13.8 | 6.1 | 17.2 | 17.7 | 0.01 |
| Carbohydrate (>70%) | 20.9 | 34.8 | 23.7 | 28.2 | 0.08 | 32.4 | 48.2 | 39.3 | 49.6 | <0.01 |

[a]Income: poverty line (low <120%), physical activity (⩾5 times per week, for ⩾30 min), carbohydrate (>70% calories from carbohydrates).
[b]The number of participants may vary due to missing values; the missing number was less than 40 cases in most variables except for income (164 cases) and carbohydrate (1274 cases).
[c]SEP: participant high (⩾ college graduates for the birth cohort of 1966–79, ⩾ high school graduates for the birth cohort of 1943–65) and low; father high (> elementary school for the birth cohort of 1966–79 and ⩾ elementary school for the birth cohort of 1943–65) and low.

**Table 3** Prevalence of biological risk factors[a,b] according to SEP (measured by educational levels) in childhood and adulthood by gender and birth cohort

| Variables | SEP level[c] in childhood and adulthood | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | | | | Women | | | | |
| | Participant (⩾14 years) | | Participant (<14 years) | | | Participant (⩾14 years) | | Participant (<14 years) | | |
| | Father (⩾6 years) | Father (<6 years) | Father (⩾6 years) | Father (<6 years) | *P* for trend | Father (⩾6 years) | Father (<6 years) | Father (⩾6 years) | Father (<6 years) | *P* for trend |
| **Birth cohort 1943–65 (%)** | | | | | | | | | | |
| Abdominal obesity | 32.6 | 34.6 | 29.2 | 30.3 | 0.22 | 21.2 | 21.5 | 38.3 | 44.6 | <0.01 |
| Overweight (BMI ⩾ 25 kg/m$^2$) | 43.1 | 44.2 | 36.5 | 38.9 | 0.02 | 24.4 | 25.4 | 42.4 | 45.0 | <0.01 |
| Hypertriglycerides | 26.1 | 24.0 | 23.6 | 25.9 | 0.73 | 9.0 | 14.5 | 14.7 | 14.8 | <0.01 |
| Low HDL | 27.2 | 31.3 | 30.1 | 27.8 | 0.61 | 43.7 | 42.2 | 49.3 | 52.8 | <0.01 |
| Hypercholesterolemia | 13.0 | 10.3 | 11.0 | 10.3 | 0.13 | 15.5 | 18.0 | 18.9 | 17.4 | 0.17 |
| IFG/or diabetes mellitus | 43.0 | 43.6 | 45.7 | 41.5 | 0.89 | 23.9 | 25.1 | 30.8 | 34.0 | <0.01 |
| **Birth cohort 1966–79 (%)** | | | | | | | | | | |
| Abdominal obesity | 26.5 | 24.5 | 28.6 | 20.2 | 0.05 | 11.5 | 8.2 | 16.8 | 19.1 | <0.01 |
| Obesity (BMI ⩾ 25 kg/m$^2$) | 42.9 | 33.2 | 42.2 | 36.5 | 0.30 | 12.2 | 11.6 | 22.5 | 22.0 | <0.01 |
| Hypertriglycerides | 22.2 | 18.4 | 25.4 | 25.8 | 0.06 | 4.9 | 4.2 | 5.8 | 6.0 | 0.30 |
| Low HDL | 26.1 | 25.6 | 29.4 | 27.8 | 0.35 | 32.8 | 37.1 | 37.7 | 44.1 | <0.01 |
| Hypercholesterolaemia | 8.1 | 8.0 | 9.3 | 8.2 | 0.82 | 3.6 | 7.3 | 4.1 | 3.6 | 0.71 |
| IFG/or Diabetes mellitus | 19.3 | 17.9 | 25.6 | 26.7 | <0.01 | 8.2 | 11.0 | 13.3 | 15.1 | <0.01 |

[a]Abdominal obesity (WC, male ⩾ 90 cm, female ⩾ 85 cm), overweight (BMI ⩾ 25 kg/m$^2$), hypertriglycerides (⩾200 mg/dl), low HDL (male <40 mg/dl, female <50 mg/dl), hypercholesterolaemia (⩾240 mg/dl) and IFG/or diabetes mellitus (⩾100 mg/dl or self-reported medication or diagnosis from doctor).

[b]The number of participants may vary due to missing values; the missing number was <50 cases in abdominal obesity and BMI except for 256 cases of HDL, and TG, respectively.

[c]SEP: participant high (⩾ college graduates for the birth cohort of 1966–79, ⩾ high school graduates for the birth cohort of 1943–65) and low; father high (> elementary school for the birth cohort of 1966–79 and ⩾ elementary school for the birth cohort of 1943–65) and low.

**Table 4** OR for the association between SEP and prevalence of IFG or T2D[a] by gender and birth cohort

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| **SEP level in adulthood/childhood** | Model 1[b] | Model 2[c] | Model 3[d] | Model 1[b] | Model 2[c] | Model 3[d] |
| **Birth cohort 1943–65** | | | | | | |
| High/high (stable high) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| High/low (improving) | 0.98 (0.75–1.28) | 0.93 (0.69–1.26) | 0.90 (0.66–1.22) | 1.01 (0.69–1.48) | 0.98 (0.65–1.47) | 0.98 (0.65–1.47) |
| Low/high (declining) | 1.03 (0.81–1.32) | 0.99 (0.75–1.29) | 1.04 (0.79–1.37) | 1.21 (0.97–1.51) | 1.17 (0.93–1.49) | 1.02 (0.80–1.31) |
| Low/low (stable low) | 0.84 (0.66–1.06) | 0.79 (0.61–1.02) | 0.80 (0.62–1.05) | 1.31 (1.04–1.66) | 1.24 (0.96–1.60) | 1.06 (0.81–1.37) |
| *P* for trend | 0.36 | 0.23 | 0.45 | 0.05 | 0.08 | 0.17 |
| **Birth cohort 1966–79** | | | | | | |
| High/high (stable high) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| High/low (improving) | 0.84 (0.55–1.29) | 0.84 (0.55–1.30) | 0.89 (0.57–1.37) | 1.35 (0.72–2.51) | 1.44 (0.77–2.71) | 1.51 (0.80–2.85) |
| Low/high (declining) | 1.50 (1.12–2.00) | 1.46 (1.09–1.96) | 1.47 (1.09–1.98) | 1.68 (1.17–2.41) | 1.55 (1.07–2.25) | 1.41 (0.97–2.06) |
| Low/low (stable low) | 1.45 (1.08–1.93) | 1.40 (1.05–1.88) | 1.54 (1.14–2.08) | 1.87 (1.30–2.69) | 1.82 (1.25–2.65) | 1.67 (1.14–2.45) |
| *P* for trend | 0.21 | 0.22 | 0.13 | 0.01 | 0.03 | 0.14 |

[a]IFG/or diabetes mellitus: $\geqslant$100 mg/dl or self-reported medication or diagnosis from doctor.
[b]Model 1: adjusted for age.
[c]Model 2: Model 1 + physical activity, depression, suicidal ideation; additionally adjusted for gender and birth cohort as follows: (i) the proportion of calories from carbohydrates for older male cohort; (ii) the proportion of calories from carbohydrates, stress, TG and HDL for older female cohort; (iii) smoking for younger male cohort; and (iv) the proportion of calories from carbohydrates, smoking and HDL for younger female cohort.
[d]Model 3: Model 2 + abdominal obesity and overweight.

## Discussion

The current study suggests an independent effect of low SEP on high blood glucose risk in the younger cohort and in women in the older cohort. Among the declining and stable low SEP groups within the younger cohort, the elevated risk for high blood glucose remained significant independent of obesity in men, but not in women with a declining SEP; adjusting for obesity attenuated the inverse relationship in women only.

A recent meta-analysis based on 23 studies reported a consistent inverse relationship between SEP and T2D and it estimated the relative risk to be OR: 1.41 (95% CI 1.28–1.51).[7] However, education itself may have been defined and classified differently, given the markedly different distribution of education over time.[11] As such, the related impact of SEP on health outcomes may not be accurately estimated without considering the birth cohort especially in a rapidly changing society.[12,13,22] Moreover, it seems that the adjustment for age without stratification by birth cohort may considerably set off the effect of education.[12]

In this study, the inverse relationship between lower SEP in adults and high blood glucose risk was found among the younger cohort in both men and women. In the older generation who experienced the Korean War and poverty, the high level of educational attainment was not essential requirement to have a high SEP. Thus, education as a SEP may have a weaker association with health outcomes given that it was not a strong predictor of income.[13] On the contrary, during the latter part of the past century, education acted as a powerful means to promote upward social mobility. Accordingly, Korea showed an unprecedented expansion of higher education compared with other OECD countries.[23] The proportion of men with college-level education or beyond, for example, was only 6.5% in the older cohort, whereas it was 45.4% in the younger cohort. Therefore, the growing importance of education over successive generations may widen the generational gap in health outcomes, including metabolic syndrome, poor self-rated health and obesity.[8,12,13]

There was a gender difference in the older cohort in relationship with SEP and high blood glucose risk, but not in the younger cohort ($P$ for interaction $>0.05$). The possible explanation for a gender difference of the older cohort might be related to the higher prevalence of overweight or abdominal obesity in women in contrast to the decreasing overweight or no particular trend of abdominal obesity in men in this study. In addition, the significant interaction ($P = 0.05$) in Model 2 disappeared after adjusting for obesity. Among the unfavourable characteristics that may cause SEP to be related to worse health outcomes, obesity is a major culprit of diabetes as it increases insulin resistance[9,24] and childhood obesity predicts lower adult SEP in women.[9] In addition, obesity-related discrimination limits upward social mobility, and this trend is found more often in women.[7,25]

The next question is why SEP in adulthood and childhood in men and women of the younger birth cohort significantly affected the risk of high blood glucose even after additionally adjusting for obesity. Although lower levels of SEP have been reported to worsen diabetes risk factors, including low birthweight,[26] smoking,[27] physical inactivity, poor dietary behaviours, and obesity,[2,8,9] unfavourable characteristics could not fully explain inverse SEP gradients in the risk of T2D.[7] Some literature supports our finding of an inverse relationship between lower SEP and elevated risk of high blood glucose among younger men.[6,28,29] However, no clear mechanism relating SEP with high blood glucose was observed in younger male participants in this study. It may indicate that other unexplained factors related to power inequalities, such as long-term stress or working conditions may be involved in the relationship between SEP and high blood glucose.[7] The long-term stress, for example, is related to low SEP and affects the neuroendocrine system, including endocrine perturbations that may lead to T2D.[7]

The interpretation of our findings should take into account several limitations. First, this study was derived from cross-sectional data. Accordingly, characteristics in the distribution of all potential confounders among the lower SEP may be the result of diabetes. However, the possibility of reverse causality of SEP and high blood glucose may be very low, as our study defined SEP by measures determined early in life before the onset of high blood glucose. Secondly, this study could not dissociate the age effect from the cohort effect. We may, for example, assume that the stronger effect of SEP on high blood glucose among the younger cohort than among the older cohort was simply caused by earlier onset of high blood glucose in the lower SEP group or selective survival of the more educated group among the older cohort. To address this issue, studies comparing socio-economic groups within the same age band from different cohorts are required. Thirdly, the SEP in childhood was obtained retrospectively during adulthood based on participants' recall. The overestimation of SEP in childhood may be possible, which could have led to underestimation of the relationship between SEP and high blood glucose. Fourthly, nutrient intake was estimated by a single 24-h recall method, which seems not to reflect the long-term intake habit relating to the risk of diabetes mellitus.

Despite the limitations mentioned above, we are not aware of any previous study that has examined the relationship between educational gradient both in adulthood and childhood and diabetes mellitus by birth cohort in Asians. In addition, we included various risk factors ranging from health behaviours, psychosocial factors and diet indicators to assess the effect of SEP on high blood glucose. Moreover, KNHANES was conducted during all seasons, thus seasonal variation in risk factors was minimized.

## Conclusion

The results of this study suggest that the relationship between SEP in childhood and adulthood and the risk of high blood glucose was stronger in both men and women in the younger cohort (1966–79) compared with those in the older cohort (1943–65). In addition, obesity in lower SEP women may elevate the risk of high blood glucose. Considering the relative importance of diabetic risk among Asians, efforts to reduce SEP inequalities in health are warranted early in life, especially among the lowest SEP groups.

**Conflict of interest:** None declared.

**KEY MESSAGES**

- The relationship between lower SEP and elevated risk of high blood glucose was stronger in the younger birth cohort (1966–79) than in the older birth cohort (1943–65) in Korea.
- Obesity in lower SEP women may elevate the risk of high blood glucose.
- Considering the growing importance of education over successive generations, efforts to reduce SEP inequalities in health are warranted early in life, especially among the lowest SEP groups.

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