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# Trends in socioeconomic inequalities in obesity among Korean adolescents: the Korea Youth Risk Behavior Web-based Survey (KYRBS) 2006 to 2020

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**OBJECTIVES:** This study investigated recent trends in the prevalence of obesity among Korean adolescents and explored socioeconomic disparities in obesity.

**METHODS:** This study used annual self-reported data on height, weight, and socioeconomic information from the Korea Youth Risk Behavior Web-based Survey from 2006 to 2020. With a 95.8% response rate, the sample consisted of 818,210 adolescents. Obesity prevalence was calculated according to 4 socioeconomic indicators (household income, father's educational attainment, mother's educational attainment, and urbanicity). Socioeconomic inequality was quantified using the relative index of inequality (RII).

**RESULTS:** The overall prevalence of obesity increased, doubling from 5.9% in 2006 to 11.7% in 2020. Boys and high school students showed a higher prevalence. The RIIs in household income and parental educational attainments significantly increased with time, indicating a growing inequality in obesity. Socioeconomic disadvantages had a greater influence on obesity among girls. The most recent RII values for boys were 1.25 for income, 1.79 for the father's education, and 1.45 for the mother's education, whereas the corresponding values for girls were 2.49, 3.17, and 2.62, respectively.

**CONCLUSIONS:** These findings highlight growing inequalities in adolescent obesity according to household income and parental educational attainments, especially for girls and middle schoolers.

**KEY WORDS:** Adolescent, Body mass index, Pediatric obesity, Socioeconomic disparities in health

## INTRODUCTION

Obesity in childhood and adolescence is associated with various comorbidities such as hypertension, dyslipidemia, asthma, type 2 diabetes, polycystic ovary syndrome, and other physiological symptoms and disorders [1]. Furthermore, it increases the risk of obesity and related morbidities in adulthood, including cardiovascular disease [2]. In this context, the escalating prevalence of childhood obesity has raised global concerns. Since the early 2000s, many studies have reported a plateau of childhood obesity in high-income countries, even though the prevalence remains high [3].

However, this stabilization of the prevalence does not seem to be experienced by all socioeconomic groups and regions. Previous studies have demonstrated that socioeconomic status and urbanicity are associated with childhood obesity [4,5]. A few studies have highlighted secular changes in socioeconomic gradients; in many developed countries, such as the United Kingdom, the United States, and Australia, a decline in obesity among socioeconomically advantaged children has masked an increase in marginalized

children, leading to stagnation of the overall prevalence [6-8].

In Korea, despite some achievements in risk modification for non-communicable diseases, the national prevalence of obesity has continued to rise; the proportion of adults with a body mass index (BMI) of 25 kg/m$^2$ or higher increased from 29.7% in 2009 to 38.4% in 2020, and that of adults with a BMI of 30 kg/m$^2$ or higher doubled to 8.2% [9,10]. Meanwhile, childhood obesity has not been extensively investigated since obesity at a young age was often minimized. The burden of childhood obesity has increased over time in Korea. The obesity rate among children aged 6-18 years increased from 1.7% to 11.1% for boys and from 2.6% to 8.9% for girls from 1979 to 2005 [11]. Based on the slowing rate of increase around 2005, a decrease in the obesity rate or stabilization was anticipated [12]. However, a recent study showed that the prevalence of pediatric obesity in Korea continued to increase, reaching 15% in 2017 [13].

Additionally, although considerable research has identified associations between socioeconomic factors and obesity, studies on trends in socioeconomic disparities in adolescent obesity are scarce in Korea. This study aimed to investigate recent trends in the prevalence of obesity and socioeconomic disparities in obesity among Korean adolescents from 2006 to 2020.

## MATERIALS AND METHODS

### Study population

This study used annual data from the Korea Youth Risk Behavior Web-based Survey (KYRBS) from 2006 to 2020. The KYRBS is a nationwide cross-sectional survey that assesses adolescents' health status and health-risk behaviors [14]. The Korea Disease Control and Prevention Agency (KDCA) and the Ministry of Education have been conducting the survey annually since 2005 [14]. The survey employs a stratified multistage cluster sampling design to obtain a nationally representative sample of middle school and high school students in Korea [15]. All students of each selected classroom participated anonymously by completing a self-administered web-based questionnaire in each sampled school [15]. Detailed information on the survey has been published in separate articles [15].

We analyzed all survey data collected so far, except for those in the first year of the KYRBS (2005), as it did not provide age information in months. During the study period from 2006 to 2020, an annual average of 68,000 students participated from 800 schools (400 middle and 400 high schools) by sampling 2% of total middle school and high school students and 15% of total schools in Korea. The response rate was approximately 95.8% (90.9-97.7%) [14]. We excluded participants aged less than 144 months or more than 227 months and those with missing data for sex, age, weight, height, or any socioeconomic indicator. After excluding 5,618 individuals (0.7% of the total survey respondents), the analytic sample for 15 years consisted of 818,210 adolescents aged between 12 years and 18 years.

### Measurements

Students' height and weight were self-reported in the survey, from which BMI was calculated as weight divided by height squared (kg/m$^2$). Body size and growth in childhood substantially change with age; therefore, the definition of adolescent obesity requires taking into consideration age and sex [16,17]. In this study, adolescent obesity was defined as a sex-specific BMI-for-age (in months) of the 95th percentile or greater based on the 2017 Korean National Growth Charts (KNGC). The KNGC has been nationally used as a Korean standard to evaluate children's growth and health [16,18]. It was developed using advanced statistical methods used in the Centers for Disease Control and Prevention (CDC) Growth Charts and the World Health Organization Growth Reference (WHO-GR) [16].

We used 4 indicators of socioeconomic position (SEP) to investigate socioeconomic inequalities in adolescent obesity: household income, father's educational attainment, mother's educational attainment, and urbanicity. Household income was subjectively measured on a five-point scale (highest, mid-high, middle, mid-low, and lowest) in the KYRBS. We merged and categorized them into three groups: high (highest and mid-high), middle, or low (mid-low and lowest). Parental education attainments were self-reported as basic education or less (middle school—compulsory education of 9 years and below), upper secondary education (high school), and tertiary education or above (college, university, or above). Urbanicity was determined as the location of the sampled schools. From the survey design process, the KDCA identified middle and high schools in each administrative district across the country and classified them into three groups (metropolitan cities, other cities, and rural areas) based on the size of the population and urbanization of the district [15].

### Statistical analysis

The sampling weights provided by the KDCA were applied in our analyses to extrapolate the results to the general youth population in Korea. The general characteristics of the study population were presented as weighted means with standard deviations or weighted percentages with 95% confidence intervals (CIs). We calculated the overall prevalence of obesity in the total study population and subgroups by sex or by stage of school, and then the prevalence in each subgroup according to socioeconomic status. Trend analyses were conducted for general characteristics, anthropometric measures, and overall prevalence using a linear regression model with the survey year variable.

Socioeconomic inequalities in adolescent obesity were quantified using the prevalence ratio (PR), relative index of inequality (RII), prevalence difference (PD), and slope index of inequality (SII). The PR of each socioeconomic subgroup compared to the reference was calculated from SAS PROC GENMOD's log-binomial regression analyses (version 9.4; SAS Institute Inc., Cary, NC, USA) [19]. To summarize and compare relative health inequalities between populations with different proportions of socioeconomic subgroups, the RII was also employed [20]. The RII repre-

**Table 1.** General characteristics of the study population from 2006 to 2020

| Characteristics | Year[1] | | | | | | | | | | | | | | | Annual change | p for trend[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | | |
| Total (n) | 57,511 | 60,817 | 61,804 | 60,363 | 57,749 | 61,732 | 59,724 | 56,849 | 55,934 | 52,166 | 50,310 | 47,241 | 45,291 | 47,095 | 43,624 | | |
| Age, mean (yr) | 15.07 | 15.12 | 15.12 | 15.21 | 15.24 | 15.28 | 15.08 | 15.11 | 15.15 | 15.22 | 15.25 | 15.26 | 15.29 | 15.19 | 15.31 | -0.001 | 0.021 |
| Subgroups | | | | | | | | | | | | | | | | | |
| Sex | | | | | | | | | | | | | | | | | |
| Boys | 51.2 | 51.5 | 51.9 | 52.0 | 52.0 | 51.6 | 51.6 | 51.4 | 50.9 | 51.1 | 51.3 | 51.2 | 51.1 | 52.1 | 51.6 | 0.000 | 0.646 |
| Girls | 48.8 | 48.5 | 48.1 | 48.0 | 48.0 | 48.4 | 48.4 | 48.6 | 49.1 | 48.9 | 48.7 | 48.8 | 48.9 | 47.9 | 48.4 | 0.000 | 0.646 |
| Stage | | | | | | | | | | | | | | | | | |
| High school | 49.2 | 51.1 | 51.3 | 52.7 | 53.3 | 53.7 | 54.5 | 55.4 | 55.6 | 56.5 | 58.3 | 58.1 | 56.9 | 54.7 | 53.6 | 0.001 | <0.001 |
| Middle school | 50.8 | 48.9 | 48.7 | 47.3 | 46.7 | 46.3 | 45.5 | 44.6 | 44.4 | 43.5 | 41.7 | 41.9 | 43.1 | 45.3 | 46.4 | -0.001 | <0.001 |
| Socioeconomic factors | | | | | | | | | | | | | | | | | |
| Household income | | | | | | | | | | | | | | | | | |
| High | 32.6 | 29.9 | 30.4 | 30.0 | 31.8 | 32.3 | 32.4 | 34.3 | 35.9 | 38.8 | 39.7 | 43.0 | 44.1 | 41.1 | 42.0 | 0.012 | <0.001 |
| Middle | 47.5 | 47.2 | 47.1 | 47.1 | 46.4 | 46.4 | 46.3 | 46.5 | 47.2 | 45.5 | 46.0 | 44.0 | 44.1 | 47.2 | 46.1 | -0.002 | <0.001 |
| Low | 19.9 | 22.9 | 22.5 | 23.0 | 21.8 | 21.3 | 21.4 | 19.2 | 16.9 | 15.6 | 14.3 | 12.9 | 11.8 | 11.7 | 11.8 | -0.010 | <0.001 |
| Father's education | | | | | | | | | | | | | | | | | |
| Tertiary or above | 45.7 | 47.2 | 49.3 | 51.0 | 53.3 | 54.8 | 55.1 | 56.7 | 60.3 | 63.0 | 63.8 | 66.3 | 68.7 | 69.9 | 71.7 | 0.011 | <0.001 |
| Upper secondary | 45.6 | 45.3 | 43.7 | 42.5 | 40.8 | 40.2 | 40.4 | 39.4 | 36.4 | 34.2 | 33.8 | 31.5 | 29.6 | 28.3 | 26.7 | -0.018 | <0.001 |
| Basic or less | 8.7 | 7.5 | 7.0 | 6.5 | 5.9 | 5.0 | 4.5 | 3.9 | 3.3 | 2.8 | 2.4 | 2.1 | 1.7 | 1.8 | 1.6 | -0.007 | <0.001 |
| Mother's education | | | | | | | | | | | | | | | | | |
| Tertiary or above | 30.3 | 31.1 | 34.3 | 36.8 | 39.2 | 41.6 | 43.1 | 45.9 | 50.5 | 54.4 | 56.4 | 59.8 | 63.5 | 65.8 | 67.8 | 0.021 | <0.001 |
| Upper secondary | 59.2 | 60.0 | 58.3 | 56.6 | 54.8 | 53.3 | 52.4 | 50.4 | 46.6 | 43.1 | 41.6 | 38.4 | 35.1 | 32.8 | 31.1 | -0.026 | <0.001 |
| Basic or less | 10.5 | 8.9 | 7.4 | 6.6 | 6.0 | 5.1 | 4.5 | 3.8 | 2.8 | 2.4 | 2.1 | 1.8 | 1.5 | 1.4 | 1.1 | -0.008 | <0.001 |
| Urbanicity | | | | | | | | | | | | | | | | | |
| Metropolitan cities | 47.2 | 46.6 | 55.2 | 54.7 | 45.7 | 45.3 | 44.8 | 44.7 | 43.9 | 44.3 | 43.7 | 43.9 | 43.7 | 43.2 | 42.9 | -0.005 | <0.001 |
| Other cities | 45.2 | 47.1 | 39.6 | 40.2 | 48.1 | 48.7 | 49.3 | 48.6 | 49.9 | 49.8 | 50.8 | 50.3 | 50.7 | 51.5 | 51.5 | 0.010 | <0.001 |
| Rural areas | 7.6 | 6.3 | 5.2 | 5.1 | 6.2 | 5.9 | 6.0 | 6.7 | 6.2 | 5.9 | 5.4 | 5.8 | 5.6 | 5.3 | 5.5 | -0.006 | <0.001 |

Values are presented as %.
[1] The corresponding standard deviation and 95% confidence interval are presented in the supplementary document.
[2] The p-value for trend was tested for each row of the table.

**Table 2.** Self-reported anthropometric measures and overall prevalence of obesity defined by various growth references

| Variables | Year | | | | | | | | | | | | | | | Annual change | p for trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | | |
| **Height (cm)** | | | | | | | | | | | | | | | | | |
| Total | 165.1 | 165.4 | 165.4 | 165.7 | 165.6 | 165.7 | 165.1 | 165.2 | 165.3 | 165.6 | 165.7 | 165.9 | 166.1 | 166.0 | 166.6 | 0.057 | <0.001 |
| Sex | | | | | | | | | | | | | | | | | |
| Boys | 169.8 | 170.1 | 170.1 | 170.6 | 170.6 | 170.8 | 170.0 | 170.2 | 170.4 | 170.7 | 170.9 | 171.1 | 171.3 | 171.1 | 171.8 | 0.090 | <0.001 |
| Girls | 160.2 | 160.4 | 160.3 | 160.3 | 160.3 | 160.2 | 160.0 | 160.0 | 160.0 | 160.3 | 160.3 | 160.4 | 160.5 | 160.5 | 161.0 | 0.024 | <0.001 |
| Stage | | | | | | | | | | | | | | | | | |
| High school | 167.6 | 167.8 | 167.8 | 168.0 | 168.0 | 167.9 | 167.5 | 167.5 | 167.5 | 167.5 | 167.6 | 167.8 | 167.9 | 168.1 | 168.5 | 0.026 | <0.001 |
| Middle school | 162.7 | 162.8 | 162.9 | 163.0 | 162.9 | 163.1 | 162.3 | 162.4 | 162.6 | 163.2 | 163.1 | 163.3 | 163.6 | 163.5 | 164.4 | 0.082 | <0.001 |
| **Weight (kg)** | | | | | | | | | | | | | | | | | |
| Total | 56.4 | 56.5 | 56.4 | 56.6 | 56.6 | 56.8 | 56.6 | 57.0 | 57.1 | 57.7 | 58.4 | 58.8 | 59.3 | 59.3 | 60.1 | 0.243 | <0.001 |
| Sex | | | | | | | | | | | | | | | | | |
| Boys | 60.8 | 60.8 | 60.8 | 61.2 | 61.4 | 61.3 | 60.9 | 61.3 | 61.7 | 62.2 | 63.3 | 64.1 | 64.7 | 64.7 | 66.1 | 0.327 | <0.001 |
| Girls | 51.9 | 51.8 | 51.7 | 51.6 | 51.5 | 52.0 | 52.0 | 52.5 | 52.4 | 53.0 | 53.3 | 53.4 | 53.6 | 53.5 | 53.6 | 0.156 | <0.001 |
| Stage | | | | | | | | | | | | | | | | | |
| High school | 59.8 | 59.6 | 59.4 | 59.5 | 59.5 | 59.6 | 59.5 | 59.9 | 60.1 | 60.5 | 61.2 | 61.7 | 62.2 | 62.5 | 62.9 | 0.250 | <0.001 |
| Middle school | 53.2 | 53.1 | 53.3 | 53.3 | 53.3 | 53.5 | 53.1 | 53.4 | 53.5 | 54.0 | 54.5 | 54.9 | 55.4 | 55.4 | 56.9 | 0.223 | <0.001 |
| **BMI (kg/m$^2$)** | | | | | | | | | | | | | | | | | |
| Total | 20.6 | 20.5 | 20.5 | 20.5 | 20.5 | 20.6 | 20.6 | 20.8 | 20.8 | 20.9 | 21.1 | 21.3 | 21.4 | 21.4 | 21.5 | 0.072 | <0.001 |
| Sex | | | | | | | | | | | | | | | | | |
| Boys | 21.0 | 20.9 | 20.9 | 20.9 | 21.0 | 20.9 | 21.0 | 21.1 | 21.1 | 21.2 | 21.6 | 21.8 | 21.9 | 22.0 | 22.3 | 0.089 | <0.001 |
| Girls | 20.2 | 20.1 | 20.1 | 20.0 | 20.0 | 20.2 | 20.3 | 20.5 | 20.4 | 20.6 | 20.7 | 20.7 | 20.8 | 20.7 | 20.6 | 0.054 | <0.001 |
| Stage | | | | | | | | | | | | | | | | | |
| High school | 21.2 | 21.1 | 21.0 | 21.0 | 21.0 | 21.1 | 21.1 | 21.3 | 21.3 | 21.5 | 21.7 | 21.8 | 21.9 | 22.0 | 22.0 | 0.080 | <0.001 |
| Middle school | 20.0 | 20.0 | 20.0 | 19.9 | 20.0 | 20.0 | 20.1 | 20.1 | 20.1 | 20.2 | 20.4 | 20.5 | 20.6 | 20.6 | 20.9 | 0.061 | <0.001 |
| **Overall obesity (%)** | | | | | | | | | | | | | | | | | |
| **BMI ≥95th percentile (2017 KNGC)** | | | | | | | | | | | | | | | | | |
| Total | 5.9 | 5.2 | 5.3 | 5.1 | 5.3 | 5.5 | 6.1 | 6.5 | 6.8 | 7.3 | 8.8 | 9.7 | 10.6 | 10.9 | 11.7 | 0.005 | <0.001 |
| Sex | | | | | | | | | | | | | | | | | |
| Boys | 7.5 | 6.7 | 6.7 | 6.6 | 7.0 | 6.7 | 7.4 | 7.9 | 8.4 | 8.6 | 10.9 | 12.0 | 13.1 | 13.5 | 15.1 | 0.006 | <0.001 |
| Girls | 4.2 | 3.7 | 3.7 | 3.5 | 3.4 | 4.2 | 4.7 | 5.0 | 5.0 | 5.9 | 6.6 | 7.3 | 7.9 | 8.1 | 8.0 | 0.004 | <0.001 |
| Stage | | | | | | | | | | | | | | | | | |
| High school | 6.6 | 6.0 | 5.8 | 5.4 | 5.6 | 5.8 | 6.6 | 7.3 | 7.4 | 8.5 | 10.0 | 11.0 | 12.1 | 12.6 | 12.9 | 0.006 | <0.001 |
| Middle school | 5.2 | 4.5 | 4.7 | 4.9 | 5.1 | 5.1 | 5.5 | 5.5 | 5.9 | 5.7 | 7.2 | 7.8 | 8.5 | 8.8 | 10.2 | 0.004 | <0.001 |
| **BMI ≥95th percentile (WHO-GR)** | | | | | | | | | | | | | | | | | |
| Total | 6.3 | 5.8 | 5.9 | 5.6 | 5.9 | 5.8 | 6.5 | 7.0 | 7.1 | 7.5 | 8.9 | 9.6 | 10.6 | 11.2 | 12.2 | 0.005 | <0.001 |
| Sex | | | | | | | | | | | | | | | | | |
| Boys | 10.3 | 9.6 | 9.6 | 9.3 | 9.8 | 9.3 | 10.4 | 11.1 | 11.4 | 11.5 | 13.8 | 14.7 | 16.4 | 17.0 | 18.9 | 0.007 | <0.001 |
| Girls | 2.1 | 1.7 | 1.9 | 1.7 | 1.6 | 2.1 | 2.5 | 2.7 | 2.6 | 3.3 | 3.7 | 4.2 | 4.5 | 4.9 | 5.1 | 0.003 | <0.001 |
| Stage | | | | | | | | | | | | | | | | | |
| High school | 4.5 | 4.2 | 4.0 | 3.8 | 3.9 | 4.0 | 4.6 | 5.3 | 5.3 | 6.1 | 7.6 | 8.3 | 9.1 | 9.8 | 9.9 | 0.005 | <0.001 |
| Middle school | 8.0 | 7.4 | 7.9 | 7.7 | 8.1 | 7.9 | 8.9 | 9.2 | 9.3 | 9.2 | 10.7 | 11.4 | 12.6 | 12.9 | 14.9 | 0.005 | <0.001 |
| **BMI>median+2SD (WHO-GR)** | | | | | | | | | | | | | | | | | |
| Total | 2.7 | 2.4 | 2.6 | 2.4 | 2.6 | 2.4 | 2.9 | 3.2 | 3.4 | 3.5 | 4.5 | 4.9 | 5.6 | 6.1 | 6.7 | 0.003 | <0.001 |
| Sex | | | | | | | | | | | | | | | | | |
| Boys | 5.1 | 4.5 | 4.7 | 4.4 | 4.8 | 4.2 | 5.1 | 5.5 | 6.1 | 6.0 | 7.8 | 8.3 | 9.5 | 10.0 | 11.1 | 0.005 | <0.001 |
| Girls | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.4 | 0.6 | 0.6 | 0.8 | 1.1 | 1.3 | 1.5 | 1.8 | 2.0 | 0.001 | <0.001 |
| Stage | | | | | | | | | | | | | | | | | |
| High school | 1.7 | 1.7 | 1.6 | 1.3 | 1.5 | 1.3 | 1.7 | 2.2 | 2.4 | 2.7 | 3.7 | 4.0 | 4.7 | 5.3 | 5.1 | 0.003 | <0.001 |
| Middle school | 3.7 | 3.2 | 3.6 | 3.6 | 3.9 | 3.6 | 4.2 | 4.3 | 4.7 | 4.5 | 5.7 | 6.2 | 6.7 | 7.0 | 8.5 | 0.003 | <0.001 |

BMI, body mass index; 2017 KNGC, the 2017 Korean National Growth Charts; WHO-GR, the World Health Organization Growth Reference; SD, standard deviations.
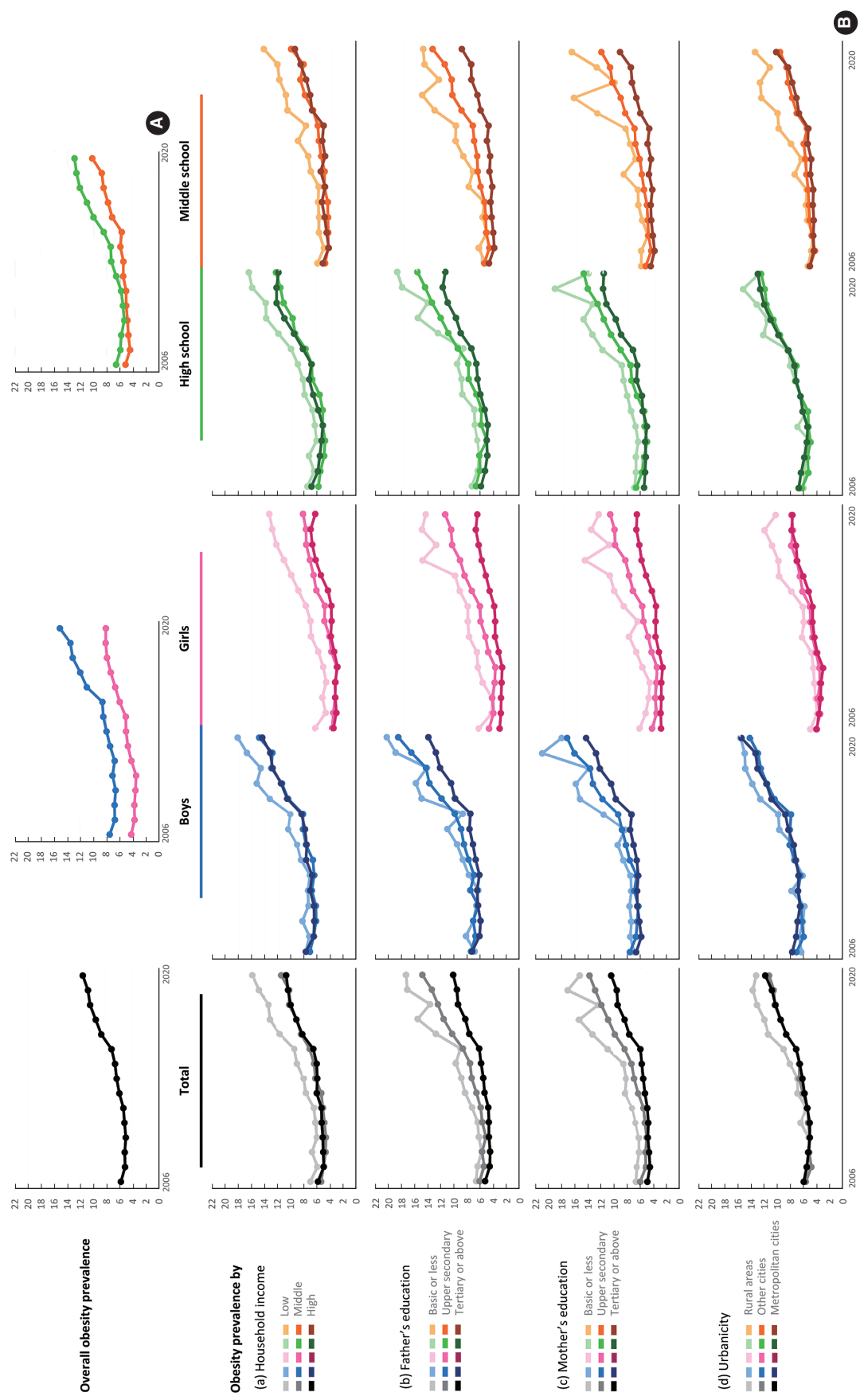
**Figure 1.** Trends in obesity prevalence among the Korean adolescents from 2006 to 2020. (A) Overall prevalence of the total study population, boys and girls, and middle- and high school students. (B) Obesity prevalence of the total and subgroups according to each of four socioeconomic factors.
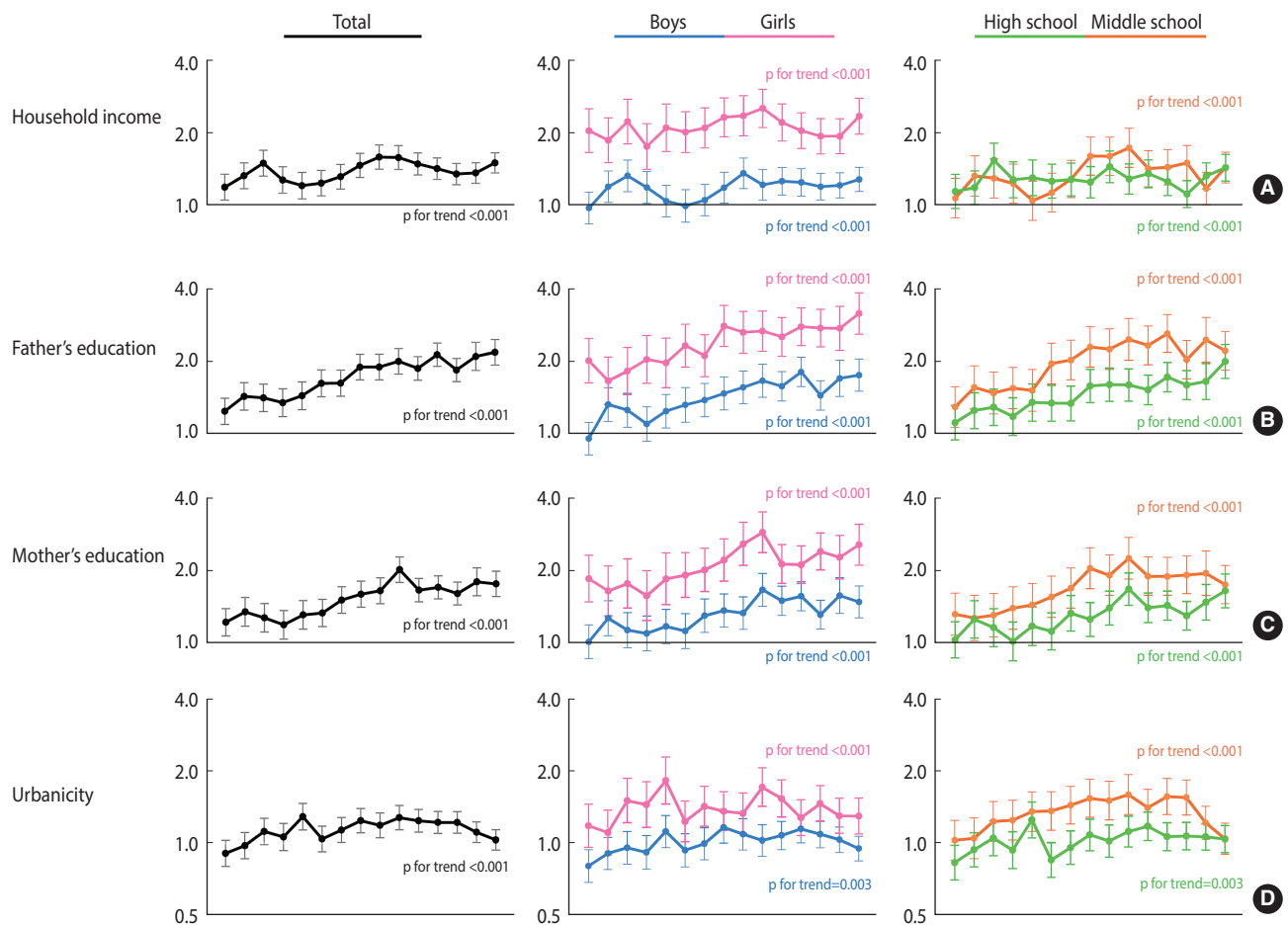
**Figure 2.** The trends of relative index of inequality based on prevalence ratio according to (A) household income, (B) father's educational attainment, (C) mother's educational attainment, and (D) urbanicity of school from 2006 to 2020. The closed vertical lines represent the 95% confidence intervals.

## DISCUSSION

Using 15-year trend analyses of a nationwide representative survey of Korean adolescents, this study showed that both the prevalence of adolescent obesity and socioeconomic inequalities in adolescent obesity increased between 2006 and 2020. A greater disparity was observed between students with highly educated parents and those with less educated parents, which significantly widened. In subgroup analyses, all 4 types of socioeconomic inequalities were found in all sex and school-stage subgroups. However, their magnitudes were greater in girls and middle school students. Notably, the absolute prevalence rates were higher in boys and high school students.

Korea has a relatively well-established health system and intends to respond to the rapid epidemiological transition of obesity [23]. Despite academic and political efforts, obesity is increasing not only in adults but also in children, as observed in the current study [9]. Given that adolescent obesity seems to have stabilized in many developed countries, the increasing prevalence in Korea is notable

[3]. This would threaten the current health of Korean youths and aggravate the burden on health care in the future. Meanwhile, the high obesity rates among children appear to be valid, even after considering the likelihood of short stature. Although high BMI due to low height was not expected to be as prevalent in Korea as in low-income or middle-income countries, it could be misinterpreted as excess body weight. We additionally analyzed the prevalence of stunting, which was defined as height-for-age less than 2 standard deviations from the median based on the 2017 KNGC. A negative correlation was observed between SEP and stunting, although the prevalence was low (Supplementary Material 9). When calculating cases of a high BMI due to stunting, the absolute number was extremely low (Supplementary Material 10). Hence, the interpretation seems valid that short stature was unlikely to lead to a high obesity rate among Korean youth, and the prevalence of excess body weight increased.

Moreover, the growing inequality of adolescent obesity is alarming; the increase in obesity risk among socioeconomically deprived children was greater than the rise among the advantaged. One

study in Australia reported RIIs of 1.16 for boys and 1.15 for girls in annual BMI growth according to adolescents' SEP defined with a composite variable [24]. Another study using the combined data from 11 European cohorts demonstrated an RII of 1.58 (95% CI, 1.34 to 1.85) for overweight and 2.61 (95% CI, 2.10 to 3.23) for obesity according to maternal education [25]. Recognizing limitations in the global comparison of socioeconomic inequality due to sample characteristics and study designs, Korea's high inequality presented as RIIs highlights the need to closely monitor the social gradient in adolescent obesity.

Previous studies have found that household economic status has a substantial impact on obesity in the youth. Nevertheless, the direction of inequality differs according to the economic level of the country or racial and cultural backgrounds [26,27]. Obesity is concentrated among the advantaged in developing countries, but among the disadvantaged in high-income countries [26]. A study in the United States demonstrated a protective effect of high family income against obesity in White, but not in Black children [27]. This suggests that various factors are associated with household economic level and the discriminated risk of adolescent obesity: social perceptions of obesity, affordability of a healthy diet, accessibility to healthcare, health literacy, physical activity, and so forth [28].

In our study, the influence of inequality according to parents' educational attainments was greater than that of the other indicators, and the increasing trend was more evident. A negative correlation between parental educational attainments and childhood obesity has also been observed in other countries. One study pointed out that the stabilized prevalence of obesity masked the increasing disparity according to parents' education levels [6]. Since 2002, youth who had highly educated parents showed a decreasing trend in the prevalence of obesity, whereas obesity in those having parents with low educational attainment continued to increase. The escalating trend in inequality among Korean youth differs from that of other countries: the prevalence increased in all socioeconomic groups in Korea, but with a more substantial magnitude in the socioeconomically disadvantaged.

Compared to other socioeconomic factors, the effect of urbanicity on adolescent obesity was fairly small. Among boys and high schoolers, the recent RIIs were around the value of 1, indicating no significant inequality. Only a slight rural disadvantage was observed among female students and middle school students. Previous research on urban-rural disparities has shown various results by country: Obesity was concentrated in urban areas in low-income and middle-income countries, but in rural areas in high-income countries [26]. Moreover, other studies reported no differences in obesity prevalence between rural and urban areas in 10 European countries [29]. Another study provided possible explanations for our findings: Rural disadvantages may be due to high prevalence of energy-dense dietary intake, sedentary lifestyle, and physical inactivity among girls and middle school students in rural areas [5,30]. The lack of urban-rural differences, however, in boys and high school students could imply that the possible

mechanisms linking urbanicity and adolescent obesity are sex-specific in Korea. Further research is required to comprehend the sex-specific risk factors associated with regional disparities in obesity prevalence.

Across all socioeconomic factors, our findings illustrated that social gradients had a greater influence on female adolescents. Sex differences in socioeconomic inequality of obesity were globally reported in adult populations, but not observed in children in most countries [9,12]. In Korea, a higher risk of obesity was demonstrated in both female adults and adolescents with a lower socioeconomic background [31]. Few studies have elucidated the direct cause of the higher vulnerability of female students to socioeconomic inequality, although it is known that female students engage in less physical activity and more sedentary behavior than male students [32]. A possible explanation is that low SEP has a greater impact on health behaviors in females, or that it mediates between obesity and women's biological factors. For instance, girls at low SEP are likely to have an earlier onset of menarche, which may increase the risk of obesity via its hormonal and metabolic effects [33].

Similarly, middle school students had a greater vulnerability to social gradients compared to high school students. It could be, at least partly, explained by younger children being more dependent on their nurturing environment. Young adolescents are more prone to poorer health behaviors when they receive less parental supervision and guidance, which often occurs in dual-income families. Studies on the association between maternal work hours and childhood obesity have found that children whose mothers work are more likely to be sedentary and consume low-quality food [25,34]. Prior research also reported a negative correlation between the father's education level and the offspring's obesity, although the correlation weakened as the offspring became older [35].

Our study has some strengths: the KYRBS is conducted annually nationwide with a high response rate–approximately 95.8%, and it includes various socioeconomic information. This allowed us to obtain a representative sample of Korean adolescents and to analyze the trend of obesity according to socioeconomic status. To our knowledge, this is the first study to highlight secular trends in socioeconomic inequalities in obesity among Korean adolescents using recent multiyear data. The limitations of this study should also be considered. First, height and weight were self-reported and were not measured. Previous studies on the accuracy of self-reported height and weight in assessing obesity pointed out biased BMI values as a concern: specifically, adolescents underreport weight and overreport height, which results in an underestimation of their BMI [36]. This implies that the actual prevalence of obesity may have been higher than that observed in our study. We additionally analyzed the prevalence of adolescent obesity using measured data from the Korea National Health and Nutrition Examination Survey from 2007 to 2020. These figures were higher than the prevalence from self-reported data (Supplementary Material 11). Nonetheless, the increasing trend in prevalence persisted in our additional analysis. Moreover, a previous

study measured the height and weight of the 2008 KYRBS participants, and compared them with self-reported data. It found that the sensitivity of obesity was 69% and the specificity was 100%, while the kappa value was 0.79 (95% CI, 0.70 to 0.88) [37]. As the KYRBS collected self-reported data on all occasions, the trend of obesity is reliable while recognizing the chance of underestimation. Second, although the data were collected via national sampling, the results may not be extrapolated to the general population of Korean adolescents. We could not include youths outside of school in this study, and they are likely socioeconomically marginalized. Last, we used a Korean growth reference. This might hinder comparison at the global level. In the 2017 KNGC, the BMI values at the 95th percentile during the transition from adolescence to adulthood converged at approximately 25 kg/m$^2$, whereas the corresponding values from the WHO and CDC met at around 30 kg/m$^2$. Nonetheless, there has been debate regarding the use of a BMI cut-off of 30 kg/m$^2$ to define obesity in the Asian population [38]. Using the higher cut-off may hinder screening for obesity in Asian populations and underestimate their related health risks [39]. In this context, it seems appropriate to use the Korean growth standard to evaluate the growth and development of adolescents.

This study illustrated increasing trends in the prevalence of obesity and growing socioeconomic inequalities in obesity among Korean youth. The widening socioeconomic gap resulted from the greater increase in obesity among the low-SEP group than among the high-SEP group. To tackle both the increasing prevalence and widening inequality, relevant policies and interventions should target disadvantaged girls and middle school students as well as boys and high school students.

## SUPPLEMENTARY MATERIALS

Supplementary materials are available at http://www.e-epih.org/.

## CONFLICT OF INTEREST

The authors have no conflicts of interest to declare for this study.

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## AUTHOR CONTRIBUTIONS

Conceptualization: Kim E, Kim HC. Data curation: Kim E. Formal analysis: Kim E. Funding acquisition: None. Methodology:

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