Trends in body mass index changes among Korean adolescents between 2005-2020, including the COVID-19 pandemic period: a national representative survey of one million adolescents

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Abstract. – OBJECTIVE: The impact of the coronavirus disease 2019 (COVID-19) pandemic on weight gain in children and adolescents remains unknown. We aimed to identify an estimated 15-year trend in mean body mass index (BMI) changes and prevalence of obesity and overweight among Korean adolescents from 2005 to 2020, including the period of the COVID-19 pandemic.

PATIENTS AND METHODS: We analyzed data taken from a nationwide survey (Korea Youth Risk Behavior Survey), between 2005 and 2020. Representative samples of one million Korean adolescents aged 13-18 years (n=1,057,885) were examined. The 15-year trends in mean BMI and proportion of obesity or overweight, and the changes due to the COVID-19 pandemic were analyzed.

RESULTS: The data of 1,057,885 Korean adolescents were analyzed (mean age: 14.98 years; females, 48.4%). The estimated weighted mean BMI was 20.5 kg/m^2 [95% confidence interval (CI), 20.4-20.5] from 2005 to 2008 and 21.5 kg/m^2 (95% CI, 21.4-21.6) in 2020 (during the COVID-19 pandemic). Although the 15-year trend of mean BMI gradually increased, the change in mean BMI before and during the pandemic significantly lessened (βdiff, -0.027; 95% CI, -0.028 to -0.026). The 15-year (2005-2020) trend changes in the prevalence of obesity and overweight were similar (obesity prevalence from 2005-2008, 3.2%; 95% CI, 3.1-3.3 *vs.* obesity prevalence in 2020, 8.6%; 95% CI, 8.2-9.0; βdiff, -0.309; 95% CI, -0.330 to -0.288).

CONCLUSIONS: The 15-year trend of overall mean BMI and obesity and overweight prevalence demonstrated a significant increase; however, its slope decreased during the pandemic. These landmark results suggest the need for the development of precise strategies to prevent pediatric obesity and overweight during the COVID-19 pandemic.

Key Words:
COVID-19, BMI, Obesity, Overweight, Adolescent, KYRBS.

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Introduction

The prevalence of obesity and overweight in children and adolescents is increasing worldwide, and the public health consequences are becoming a major issue globally[1,2]. Obesity and overweight are influenced by complex interactions among diverse factors, such as lifestyle, physical activity, and comorbidities[3]. Obese children, especially adolescents, are likely to remain obese adults, and the adverse physical and psychological effects related to obesity are likely to persist into adulthood[4]. Therefore, it is important to identify the rate of obesity in adolescents and childhood for preventing adulthood obesity.

The coronavirus disease 2019 (COVID-19) pandemic has drastically altered the behavioral traits of people across society[3,5]. In line with government policies for social distancing, changes such as school closures, disrupted dietary habits, and decreased physical activity increased the risk of weight gain[6]. Moreover, adolescents followed an alternate schedule for online classes and cut back on all activities outside their homes, including social gatherings[7]. Several scholars[8] have reported the association of COVID-19 with weight gain in adults. Although adolescents are expected to gain more weight due to restricted activities, such as online classes and social distancing, studies on this age group are lacking[9].

Therefore, this study aimed to investigate an estimated 15-year trend in mean body mass index (BMI) changes and the prevalence of obesity and overweight among one million Korean adolescents. We used data from the national representative Korea Youth Risk Behavior Survey (KYRBS) disseminated from 2005 to 2020, including the COVID-19 pandemic period. Additionally, we evaluated the pandemic-related weight changes in adolescents and compared the BMI trends of Korean adolescents during the pre-pandemic period (2005-2009) and during the pandemic (2020).

Patients and Methods

Study Population

We used the 2005-2020 data from the KYRBS[10], supervised by the Korea Disease Control and Prevention Agency (KDCA) and Ministry of Education, to establish and evaluate government policies. Data were used to investigate health behaviors of a national representative sample of adolescents. The KYRBS selected the study population by applying a two-step stratification in the order of school and class, with details specified on the official website of the KDCA (http://www.kdca.go.kr/yhs/). The participants completed a web-based survey in computer laboratories at their respective schools. The KYRBS sampling procedures were performed to account for sample weights, clustering, and stratification to provide national representative estimates of the total Korean adolescent population[10]. These data were voluntarily gathered with a response rate of over 95%[10]. All adolescents (age 12-18 years, middle-high school) in this database were included in the present study. Participants with missing data were excluded from the study. The study protocol was approved by the KCDA and Sejong University (SJU-HR-E-2020-003).

Variable Definitions

Body mass index (BMI) was calculated from the participant's self-reported height and weight and classified, using age- and sex-specific equations from the 2007 Korean national growth charts, into: underweight (< 5th percentile), normal (5-84th percentile), overweight (85-94th percentile), and obesity (≥ 95th percentile)[11]. The areas of residence were classified as urban (Seoul, Gyeonggi, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, and Sejong) or rural (Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju) areas[12,13]. Smoking was defined as having smoked a cigarette at least once within the last 30 days[14]. Parents' educational levels were determined based on the highest educational level of either parent (high school or lower, college or higher, and unknown)[10]. Economic status and school performance were classified as high, middle-high, middle, middle-low, or low. Parents' educational levels, economic status, and school performance were self-reported[15].

Statistical Analysis

We used KYRBS data (2005-2020) to calculate the trend of mean BMI or proportion of obesity and overweight, stratified by sex, grade, and area of residence. The primary endpoint was the change in the mean BMI over a 15-year period, and the secondary endpoints were the 15-year trends for prevalence of obesity and overweight. We aimed to evaluate the impact of COVID-19 pandemic on the trends of obesity prevalence and compared these trends before and during the pandemic.

To stabilize the prevalence of obesity and overweight, the pre-COVID-19 period was set based on the KYRBS cycle of four consecutive years. Weighted complex sampling analysis with binary and linear logistic regression models and Fisher's exact tests were performed. The results are presented as weighted odds ratios (ORs) with 95% confidence intervals (CIs) or weighted β-coefficients with 95% CIs. In linear regression, the KYRBS cycle was included as a continuous variable [2005-2008, 2009-2012, 2013-2016, 2017-2019, and 2020 (COVID-19 pandemic)]. For binary regression, the KYRBS cycle was included (2017-2019 *vs.* COVID-19 pandemic). All the analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA) and R software V.3.1.1 (R Foundation, Vienna, Austria)[16-18]. Statistical significance was defined as a two-sided *p*-value of <0.05.

Patient and Public Involvement

None of the patients were directly involved in designing the research question or conducting the research. Patients were not asked for advice on interpretation or writing of the results. There were no plans to involve patients or the relevant patient community in the dissemination of study findings at this time.

Results

From 2005 to 2020, a total of 1,057,885 adolescents were enrolled in the KYRBS, comprising 48.4% females, with a mean age of 14.98 years [standard deviation (SD): 1.74]. There were 545,460 (51.6%) participants in the 7-9th grade (middle school) and 512,425 (48.4%) in the 10-12th grade (high school). By area of residence, 573,274 (54.2%) participants lived in rural areas and 484,611 (45.8%) lived in urban areas. Based on their BMI, 53,197 (5.0%) participants were underweight (<5th percentile), 854,315 (80.8%) had a normal weight (5-85th percentile), and 101,930 (9.6%) were overweight (85-95th percentile). Table I presents the general characteristics of the study population.

Table II illustrates the national crude mean and overall, 15-year trend of the mean BMI in Korean adolescents from 2005 to 2020, including the COVID-19 pandemic period. The estimated national weighted mean BMI was 20.5 (95% CI, 20.4-20.5) between 2005 and 2008, and 21.5 (95% CI, 21.4-21.6) in 2020. Although the 15-year trend

of the mean BMI showed a gradual increase over time, the change in mean BMI before and during the pandemic was significantly decreased (βdiff, -0.027; 95% CI, -0.028 to -0.026). The difference in the slope was consistent regardless of sex (male: βdiff, -0.022; 95% CI, -0.025 to -0.019; female: βdiff, -0.037; 95% CI, -0.040 to -0.035), grade (7-9th grade: βdiff, -0.015; 95% CI, -0.017 to -0.013; 10-12th grade: βdiff, -0.032; 95% CI, -0.034 to -0.030), and area of residence (rural: βdiff, -0.031; 95% CI, -0.034 to -0.029; urban: βdiff, -0.022; 95% CI, -0.025 to -0.020).

The changes in the prevalence of obesity and overweight between 2005 and 2020 are shown in Tables III and IV and Figure 1. The national weighted prevalence of obesity was 3.2% (95% CI, 3.1-3.3) between 2005 and 2008 and 8.6% (95% CI, 8.2-9.0) in 2020. The proportion of participants with obesity increased from 2005 to 2020; however, the slope of the increasing trend was significantly decreased before and during the pandemic (βdiff, -0.309; 95% CI, -0.330 to -0.288). This trend was consistent regardless of sex, (male: βdiff, -0.265; 95% CI, -0.284 to -0.246; female: βdiff, -0.511; 95% CI, -0.544 to -0.478), grade (7-9th grade: βdiff, -0.241; 95% CI, -0.272 to -0.210; 10-12th grade: βdiff, -0.316; 95% CI, -0.368 to -0.310), and area of residence (rural: βdiff, -0.339; 95% CI, -0.368 to -0.310; urban: βdiff, -0.273: 95% CI, -0.304 to -0.242).

The national weighted prevalence of overweight and obesity was 11.8% (95% CI, 11.6-12.0) between 2005 and 2008 and 21.4% (95% CI, 20.8-22.1) in 2020. The slope for the prevalence of overweight and obesity had been positive for 15 years, but the prevalence of overweight and obesity between pre-pandemic and during the pandemic had significantly decreased (βdiff, -0.180; 95% CI, -0.194 to -0.166).

Discussion

Although several small studies on the short-term trend of prevalence of pediatric obesity have been reported[9], this is the first large-scale national representative study to compare the long-term trends in BMI changes and the prevalence of obesity and overweight among adolescents during the COVID-19 pandemic period. In this study, the 15-year trends in overall mean BMI demonstrated a significant increase, from 20.5 in 2005-2008 to 21.5 in 2020, across different sexes, age groups, and areas of residence. However, the slope of the

Table I. General characteristics of Korean adolescent participants in the KYRBS from 2005 to 2020 (total sample size = 1,057,885).

General characteristic	Total crude sample, n (%)
Total number, n (%)	1,057,885 (100.0)
Age, years, crude mean (SD)	14.98 (1.74)
Grade, crude number (%)	
7-9th grade (middle school)	545,460 (51.6)
10-12th grade (high school)	512,425 (48.4)
Sex, crude number (%)	
Female	512,520 (48.4)
Male	545,365 (51.6)
BMI, kg/m^2; crude number (%)	
Underweight (below 5th percentile)	53,197 (5.0)
Normal (5-85th percentile)	854,315 (80.8)
Overweight (85-95th percentile)	101,930 (9.6)
Obese (above 95th percentile)	48,434 (4.6)
Region of residence, crude number (%)	
Rural	573,274 (54.2)
Urban	484,611 (45.8)
Smoking, crude number (%)	228,273 (21.6)
Highest educational level of parents, crude number (%)	
High school or lower	381,258 (36.0)
College or higher	516,598 (48.8)
Unknown	160,029 (15.1)
Economic level, crude number (%)	
High	82,133 (7.8)
Middle-high	276,907 (26.2)
Middle	476,776 (45.1)
Middle-low	175,335 (16.6)
Low	46,734 (4.4)
School performance, crude number (%)	
High	129,114 (12.2)
Middle-high	268,672 (25.4)
Middle	300,760 (28.4)
Middle-low	248,238 (23.5)
Low	111,101 (10.5)

BMI, body mass index; KYRBS, Korea Youth Risk Behavior Web-based Survey; SD, standard deviation.

increase in mean BMI and prevalence of obesity and overweight decreased during the COVID-19 pandemic.

BMI is a simple and widely used method for estimating body fat mass in men and women of any age. In the Asia-Pacific region, adult obesity is defined as a BMI of 25 or more, and overweight is defined as a BMI of 23-24.9[19]. However, considering the continuous increase in height and weight in the pediatric population, obesity is assessed using percentiles of BMI by sex and age[11]. For adolescents, a BMI that is above the 95th percentile is considered obese, under the 5th percentile is underweight, and between 85-94.5 is overweight[11]. Our study analyzed 15-years' data, including the COVID-19 pandemic period of 2020, thereby allowing perception of not only the long-term trends but also the impact of the

pandemic on BMI changes. In a recent study[9] on BMI changes based on pediatric population-based Kaiser Permanente Southern California electronic health record data, the COVID-19 pandemic was associated with a significant weight gain in the pediatric population, especially among the youngest children. These results are similar to the results of our study, though we found that the slope was significantly decreased during the pandemic.

In Korea, several studies on the prevalence of pediatric obesity have been reported[20]. Although one study[21] reported that pediatric obesity was on the rise until the early 2000s[18], another showed that the prevalence of overweight and obesity among children and adolescents plateaued between 2001 and 2014[22]. Consistent with our study, another previous global study[23] demonstrated a

Table II. National weighted trend of mean BMI (95% CI) in the Korean adolescent population through the KYRBS between 2005 and 2020.

	Trends in mean BMI								
	2005 to 2008	2009 to 2012	2013 to 2016	2017 to 2019	2020 (COVID-19 pandemic)	Pre-pandemic trend, β (95% CI)[a]	Pandemic trend, β (95% CI)[a]	Trend difference, β$_{diff}$ (95% CI)	2017 to 2019 vs. 2020 (COVID-19 pandemic), OR (95% CI)[b]
BMI, kg/m^2; weighted mean (95% CI)									
Overall	20.5 (20.4 to 20.5)	20.5 (20.4 to 20.5)	20.8 (20.8 to 20.9)	21.3 (21.2 to 21.3)	21.5 (21.4 to 21.6)	**0.030 (0.029 to 0.031)**	**0.003 (0.002 to 0.004)**	**-0.027 (-0.028 to -0.026)**	**1.016 (1.010 to 1.022)**
Sex									
Male	20.8 (20.8 to 20.9)	20.9 (20.8 to 20.9)	21.2 (21.1 to 21.2)	21.8 (21.8 to 21.9)	22.3 (22.2 to 22.3)	**0.028 (0.027 to 0.030)**	**0.006 (0.005 to 0.007)**	**-0.022 (-0.025 to -0.019)**	**1.031 (1.026 to 1.036)**
Female	20.0 (20.0 to 20.1)	20.1 (20.0 to 20.1)	20.5 (20.4 to 20.5)	20.7 (20.7 to 20.8)	20.6 (20.6 to 20.7)	**0.035 (0.033 to 0.037)**	-0.002 (-0.003 to 0.000)	**-0.037 (-0.040 to -0.035)**	**0.991 (0.984 to 0.999)**
Grade, weighted % (95% CI)									
7th-9th grade (middle school)	20.0 (19.9 to 20.0)	20.0 (19.9 to 20.0)	20.2 (20.1 to 20.2)	20.6 (20.5 to 20.6)	21.0 (20.9 to 21.0)	**0.021 (0.019 to 0.022)**	**0.006 (0.005 to 0.007)**	**-0.015 (-0.017 to -0.013)**	**1.032 (1.025 to 1.039)**
10th-12th grade (high school)	21.1 (21.0 to 21.1)	21.0 (21.0 to 21.1)	21.4 (21.4 to 21.5)	21.9 (21.9 to 22.0)	22.0 (22.0 to 22.1)	**0.034 (0.032 to 0.035)**	**0.002 (0.001 to 0.003)**	**-0.032 (-0.034 to -0.030)**	1.009 (1.000 to 1.017)
Region of residence									
Rural	20.4 (20.3 to 20.4)	20.5 (20.5 to 20.5)	20.8 (20.8 to 20.9)	21.3 (21.3 to 21.4)	21.5 (21.4 to 21.5)	**0.033 (0.031 to 0.035)**	**0.002 (0.001 to 0.004)**	**-0.031 (-0.034 to -0.029)**	**1.013 (1.006 to 1.021)**
Urban	20.5 (20.5 to 20.6)	20.5 (20.5 to 20.6)	20.9 (20.8 to 20.9)	21.3 (21.2 to 21.3)	21.5 (21.4 to 21.6)	**0.026 (0.024 to 0.028)**	**0.004 (0.002 to 0.005)**	**-0.022 (-0.025 to -0.020)**	**1.020 (1.011 to 1.029)**

BMI, body mass index; CI, confidence interval; KYRBS, Korea Youth Risk Behavior Web-based Survey; OR, odds ratio. [a]Estimated β (95% CI) was derived using linear regression, and this analysis included the KYRBS cycle (2005-2008, 2009-2012, 2013-2016, 2017-2019, and 2020) as a continuous variable. [b]Estimated OR (95% CI) was calculated using binomial regression, and this analysis included the KYRBS cycle (2017-2019 vs. 2020) as a categorical variable. Numbers in bold indicate a significant difference ($p < 0.05$).

Table III. National weighted prevalence and trend of obesity (95% CI) in the Korean adolescent population through the KYRBS between 2005 and 2020.

	Trends in obesity								
	2005 to 2008	2009 to 2012	2013 to 2016	2017 to 2019	2020 (COVID-19 pandemic)	Pre-pandemic trend, β (95% CI)[a]	Pandemic trend, β (95% CI)[a]	Trend difference, β$_{diff}$ (95% CI)	2017 to 2019 vs. 2020 (COVID-19 pandemic), OR (95% CI)[b]
Obesity, weighted % (95% CI)									
Overall	3.2 (3.1 to 3.3)	3.3 (3.2 to 3.4)	4.7 (4.6 to 4.9)	7.3 (7.1 to 7.5)	8.6 (8.2 to 9.0)	**0.343 (0.325 to 0.361)**	**0.034 (0.023 to 0.046)**	**-0.309 (-0.330 to -0.288)**	**1.200 (1.132 to 1.272)**
Sex									
Male	5.1 (5.0 to 5.3)	5.1 (5.0 to 5.3)	7.0 (6.8 to 7.2)	10.6 (10.4 to 10.9)	12.7 (12.2 to 13.2)	**0.303 (0.287 to 0.320)**	**0.038 (0.028 to 0.048)**	**-0.265 (-0.284 to -0.246)**	**1.225 (1.163 to 1.291)**
Female	1.0 (0.9 to 1.1)	1.2 (1.1 to 1.2)	2.3 (2.2 to 2.4)	3.7 (3.5 to 3.8)	4.2 (3.9 to 4.5)	**0.537 (0.509 to 0.566)**	**0.026 (0.009 to 0.044)**	**-0.511 (-0.544 to -0.478)**	**1.151 (1.052 to 1.260)**
Grade, weighted % (95% CI)									
7-9th grade (middle school)	2.4 (2.3 to 2.5)	2.6 (2.5 to 2.7)	3.4 (3.3 to 3.5)	5.2 (5.0 to 5.4)	6.8 (6.4 to 7.3)	**0.300 (0.275 to 0.326)**	**0.059 (0.041 to 0.077)**	**-0.241 (-0.272 to -0.210)**	**1.348 (1.237 to 1.468)**
10-12th grade (high school)	4.1 (3.9 to 4.4)	3.9 (3.7 to 4.1)	5.9 (5.7 to 6.2)	9.1 (8.8 to 9.4)	10.4 (9.8 to 11.0)	**0.341 (0.317 to 0.365)**	**0.025 (0.011 to 0.039)**	**-0.316 (-0.344 to -0.288)**	**1.151 (1.067 to 1.242)**
Region of residence									
Rural	3.0 (2.9 to 3.2)	3.2 (3.1 to 3.3)	4.8 (4.6 to 4.9)	7.3 (7.0 to 7.6)	8.4 (7.9 to 8.9)	**0.367 (0.342 to 0.391)**	**0.028 (0.013 to 0.043)**	**-0.339 (-0.368 to -0.310)**	**1.163 (1.075 to 1.258)**
Urban	3.4 (3.2 to 3.5)	3.3 (3.2 to 3.5)	4.7 (4.5 to 4.9)	7.2 (6.9 to 7.5)	8.9 (8.3 to 9.5)	**0.315 (0.288 to 0.341)**	**0.042 (0.025 to 0.059)**	**-0.273 (-0.304 to -0.242)**	**1.252 (1.147 to 1.366)**

BMI, body mass index; CI, confidence interval; KYRBS, Korea Youth Risk Behavior Web-based Survey; OR, odds ratio. [a]Estimated β (95% CI) was derived using linear regression, and this analysis included the KYRBS cycle (2005-2008, 2009-2012, 2013-2016, 2017-2019, and 2020) as a continuous variable. [b]Estimated OR (95% CI) was calculated using binomial regression, and this analysis included the KYRBS cycle (2017-2019 vs. 2020) as a categorical variable. Numbers in bold indicate a significant difference ($p < 0.05$).

Table IV. National weighted prevalence and trend of overweight or obesity (95% CI) in the Korean adolescent population through the KYRBS between 2005 and 2020.

	Trends in overweight or obesity								
	2005 to 2008	2009 to 2012	2013 to 2016	2017 to 2019	2020 (COVID-19 pandemic)	Pre-pandemic trend, β (95% CI)[a]	Pandemic trend, β (95% CI)[a]	Trend difference, β_{diff} (95% CI)	2017 to 2019 vs. 2020 (COVID-19 pandemic), OR (95% CI)[b]
Overweight or obesity, weighted % (95% CI)									
Overall	11.8 (11.6 to 12.0)	11.9 (11.7 to 12.1)	14.6 (14.4 to 14.8)	18.9 (18.6 to 19.2)	21.4 (20.8 to 22.1)	**0.209 (0.198 to 0.220)**	**0.029 (0.021 to 0.037)**	**-0.180 (-0.194 to -0.166)**	**1.171 (1.123 to 1.222)**
Sex									
Male	15.7 (15.4 to 15.9)	15.8 (15.6 to 16.1)	18.8 (18.5 to 19.0)	24.7 (24.3 to 25.0)	29.0 (28.3 to 29.7)	**0.204 (0.194 to 0.215)**	**0.041 (0.033 to 0.048)**	**-0.163 (-0.176 to -0.150)**	**1.248 (1.201 to 1.296)**
Female	7.4 (7.2 to 7.6)	7.4 (7.2 to 7.6)	10.1 (9.9 to 10.3)	12.6 (12.3 to 13.0)	13.3 (12.7 to 13.8)	**0.237 (0.221 to 0.253)**	**0.010 (0.000 to 0.020)**	**-0.227 (-0.246 to -0.208)**	**1.057 (1.001 to 1.118)**
Grade, weighted % (95% CI)									
7-9th grade (middle school)	9.8 (9.5 to 10.0)	10.0 (9.7 to 10.2)	11.5 (11.2 to 11.7)	14.5 (14.2 to 14.9)	18.3 (17.5 to 19.1)	**0.162 (0.147 to 0.176)**	**0.053 (0.042 to 0.065)**	**-0.109 (-0.128 to -0.090)**	**1.315 (1.240 to 1.394)**
10-12th grade (high school)	14.3 (13.9 to 14.6)	13.8 (13.4 to 14.1)	17.5 (17.1 to 17.8)	22.7 (22.2 to 23.2)	24.5 (23.6 to 25.5)	**0.219 (0.204 to 0.234)**	**0.018 (0.008 to 0.029)**	**-0.201 (-0.219 to -0.183)**	**1.108 (1.046 to 1.174)**
Region of residence									
Rural	11.3 (11.0 to 11.6)	11.7 (11.5 to 12.0)	14.6 (14.3 to 14.9)	19.0 (18.5 to 19.4)	21.2 (20.4 to 22.0)	**0.229 (0.214 to 0.244)**	**0.025 (0.015 to 0.036)**	**-0.204 (-0.222 to -0.186)**	**1.147 (1.087 to 1.211)**
Urban	12.3 (12.0 to 12.6)	12.0 (11.7 to 12.3)	14.7 (14.3 to 15.0)	18.8 (18.3 to 19.3)	21.8 (20.8 to 22.8)	**0.185 (0.169 to 0.201)**	**0.034 (0.021 to 0.047)**	**-0.151 (-0.170 to -0.132)**	**1.204 (1.125 to 1.289)**

BMI, body mass index; CI, confidence interval; KYRBS, Korea Youth Risk Behavior Web-based Survey; OR, odds ratio. [†]We defined Period I as 2009-2011; Period II, 2012-2014; Period III, 2015-2017; Period IV, 2018-2019; and Period V, 2020. [a]Estimated β (95% CI) was derived using linear regression, and this analysis included the KYRBS cycle (2005-2008, 2009-2012, 2013-2016, 2017-2019, and 2020) as a continuous variable. [b]Estimated OR (95% CI) was calculated using binomial regression, and this analysis included the KYRBS cycle (2017-2019 vs. 2020) as a categorical variable. Numbers in bold indicate a significant difference ($p < 0.05$).
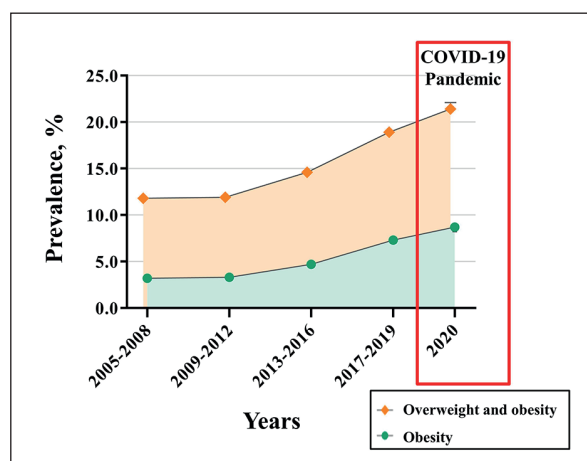
Figure 1. Nationwide trends and prevalence of obesity and overweight among one million Korean adolescents from 2005 to 2020.

plateauing of BMI and obesity trends in children and adolescents[20]. According to our study, the trend of increasing prevalence was maintained during the pre-pandemic period and pandemic periods; however, the slope of this increase notably declined during the pandemic. In other words, Korean adolescents gained less weight during the pandemic period, which is in contrast with previous studies[24,25] which showed a notable increase in children's weight gain during the COVID-19 pandemic. Thus, this is a distinctive and significant finding of our study, and to the best of our knowledge, this is the only study with this finding. In fact, previous studies found that preschool and school-aged children had greater pandemic-associated increases in BMI than adolescents did[26]. In other words, adolescents, who were examined in this study, were less affected by pandemic-associated increases in BMI.

With urbanization, rapid socio-economic transition, decreased physical activity, and altered nutritional habits, BMI has substantially increased over time[3,27,28]. During the COVID-19 pandemic, the considerable reduction in physical activity, as well as longer periods of sedentary behavior caused by the social distancing regulations, may have been the causes for weight gain[29]. Dietary habit changes have been another factor contributing to increased body weight gain. Additionally, increased time spent indoors owing to social distancing norms, unhealthy eating patterns, including delivered food or fast food, have been more common among adolescents[30]. However, these factors do not explain our finding of a less steep

slope of the prevalence of obesity or overweight during the pandemic period. Accordingly, further research is necessary to elucidate the causes of this inclination.

The greatest strength of this study is the analysis of trends based on the KYRBS data of one million Korean adolescents, which is the only database of BMI changes since the outbreak of the COVID-19 pandemic. Globally, researchers[31,32] have been unable to investigate BMI or obesity, due to various measures implemented to combat the COVID-19 pandemic, such as lockdowns.[28,29] This national representative survey was possible because the data for the survey were collected in a non-face-to-face manner prior to the pandemic. Data were collected from adolescents going through puberty through anonymous self-reported online questionnaires completed at school computer laboratories, due to the sensitivity of the survey content. Thus, the long-term trends observed in this study were not biased by differences in the survey methods.

The present study had some limitations. First, data were collected from the adolescent population of a single country (South Korea). Nonetheless, the study showed that the trend of BMI changed during the pandemic compared to before the pandemic. Additionally, the study included only one-year data of the pandemic period; however, 2020 was the year that witnessed the greatest impact of COVID-19, since restrictions such as social distancing were imposed during the first outbreak. Finally, this study was based on self-reported answers, and we did not conduct actual measurements or objective assessments. However, the reliability of the KYRBS data used in our study has been confirmed, and the kappa value for allergic diseases has been reported to be 0.74-0.80[33].

Conclusions

This is the first large-scale national representative study comparing the long-term trends in BMI and the prevalence of obesity and overweight among one million adolescents, including the period of the COVID-19 pandemic. The 15-year trends in overall mean BMI and proportion of obesity and overweight demonstrated a significant increase; however, the slope of the increase in BMI decreased during the COVID-19 pandemic, irrespective of sex, age, and area of residence. These landmark results provided an improved ep-

idemiological understanding of pediatric obesity during the COVID-19 pandemic and suggest the need for the development of precise strategies to prevent pediatric obesity and overweight during the COVID-19 pandemic.

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