



Change of obesity prevalence and lifestyle patterns before and during COVID-19 among Korean adolescents

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Purpose: Lockdown measure for limiting coronavirus disease 2019 (COVID-19) spread cause an aggravation of the childhood obesity epidemic through lifestyle changes. The aim is to investigate how social restriction might have changed obesity prevalence and lifestyle patterns in Korean adolescents. We also evaluate the most fragile group and most influencing lifestyle parameters on obesity prevalence.

Methods: To assess the change in weight status and lifestyle, we compared the Korea Youth Risk Behavior Web-based Survey data 2019 (pre-COVID-19, n=57,303) and 2020 (post-COVID-19, n=54,948). Participants from middle schools and high schools, aged 12 to 18 years, voluntarily reported their weight status and lifestyles.

Results: The prevalence of obesity of the total subjects was 11.0% in 2019 and 12.1% in 2020. This prevalence difference varied by sex (males 1.8%, females 0.3%, $P<0.001$), age group (12–15 year 1.6%, 16–18 year 0.4%, $P<0.001$), and socioeconomic status. Male aged 12–15 years showed highest increase from 12.5% to 15.2%. Physical activities, fruit intake, consumption of sugar-sweetened beverages, and stress showed all decrease. Only, nonstudy sedentary time marked increased from 3.3 ± 2.3 hr/day to 4.3 ± 2.8 hr/day. Both moderate-intensity and vigorous-intensity physical activity marked decreased especially in male aged 12–15 years, while increased in female aged 16–18 years.

Conclusion: Korean adolescents showed increasing obesity prevalence after COVID-19 lockdown, with males aged 12–15 years mainly affected, mainly due to a reduced physical activity and increased sedentary time.

Keywords: Adolescents, COVID-19, Lockdown, Obesity, Physical activity, Prevalence

Highlights

- The prevalence of obesity of the total subjects was increased during during COVID-19 lockdown and male aged 12–15 years showed highest increase.
- Decreased physical activity and increased sedentary time mostly affected adolescent who are growing and active.

Introduction

Obesity is a condition of excess body fat that negatively affects an individual's health or well-being. Childhood obesity is linked to immediate and long-term health risks.¹⁾ Furthermore, childhood obesity persists into adulthood and results in increased mortality and morbidity in later life.^{2,3)} As childhood obesity are related with an increased intake of nonhealthy diets, a sedentary lifestyle, including physical inactivity and excessive screen time. Thus, health

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professionals with governments and policymakers adopted healthy lifestyle programs in family, school, and community to prevent childhood obesity. As a result, developed countries reported that the prevalence of childhood overweight and obesity has stabilized around the early 2000s.⁴⁻⁶⁾ In the United States, the rate of obesity among children 2–19 years of age increased from 5.2% to 17.1%, from 1974 to 2004 and which did not continue to increase from 2005 to 2012.⁴⁾ In Korea, there was no significant change of obesity prevalence in children from 2001 to 2014.⁶⁾

However, the coronavirus disease 2019 (COVID-19) pandemic has caused a tremendous change in lifestyle behaviors.⁷⁻⁹⁾ Many countries have adopted the "lockdown" strategy as a means to avoid crowding. The Korea Disease Control and Prevention Agency implemented "social distancing" to prevent disease transmission.¹⁰⁾ These orders included guidelines to limit the number of people in private gatherings, prohibit large-scale events, restrict access to public facilities, close schools, limit business hours at night, and to define quarantine orders. Social distancing enforced children and adolescents are restricted to staying at home, further reducing opportunities for physical activities and exercise. Furthermore, most housebound children and adolescents are exposed to easily accessible junk food composed with high sugar and fat food sources.

Some studies have demonstrated that the prevalence of childhood obesity increased during the COVID-19 pandemic compared to that in the pre-COVID-19 period.¹¹⁻¹⁵⁾ However, most studies are based on clinic and small population. Thus, the objectives of this study were as follows: (1) to investigate whether there was a significant change in the prevalence of overweight and obesity of Korean adolescents aged 12 to 19 years in country based in 1 year during the COVID-19 pandemic; (2) to examine whether the changes are different according to sex, age group, and socioeconomic status (SES); and (3) to examine what kind of changes most affect obesity prevalence difference between 2019 and 2020.

Materials and methods

1. Subjects

This is a retrospective cross-sectional study using the Korea Youth Risk Behavior Web-based Survey 15th and 16th (KYRBWS: 2019–2020) raw data. KYRBWS is an online survey in a self-reporting format that Korea Health and Human Services and the Korea Ministry of Education, Science, and Technology have conducted annually since 2005 among middle and high school students in Korea to investigate health status using protocol of the Korea Disease Control and Prevention Agency.¹⁶⁾ The 15th cycle surveyed between June 13, 2019 and July 12, 2019. The number of respondents was 57,303 which correspond to 95.3% of 60,100 target participants (represent 2,673,152 students). The 16th cycle was conducted between August 3, 2020 and November 13, 2020. The response rate was 94.9% (n=54,948), represent 2,683,547 students. Participants

aged 12 to 18 years (7th–12th grade) from 400 middle and 400 high schools are asked to complete the web-based, self-administered questionnaire including dietary behaviors, obesity-related behaviors, physical activity, mental health, personal hygiene, injury prevention and SES, etc. anonymously. Each response has poststratification weights adjusted for nonrespondents. All participants provided written informed consent.

2. Variable measurements

Self-reported height and weight were used to calculate body mass index (BMI, kg/m²), and weight status was classified as percentile according to sex- and age-specific BMI on the 2017 Korea National Growth Chart for Children and Adolescents.¹⁷⁾ The subjects were classified as obesity (BMI ≥95th percentile), overweight (BMI ≥85th and <95th percentile), and normal weight (BMI <85th percentile), based on 2017 Korean Centers for Disease Control and Prevention growth charts. The validity of self-reported height and weight in these survey data has been evaluated in a previous study.¹⁸⁾

In the physical activity questions, moderate physical activity and vigorous-intensity physical activity were asked. Moderate physical activity was described as activity that caused slightly rapid breathing and increase heart rate compared resting time such as walking and slow swimming. Vigorous-intensity physical activity was described as activity that caused sweating and rapid breathing and was represented by jogging, fast bicycling, soccer, or similar activities. Moderate-intensity aerobic physical activity for more than 60 min/day, vigorous-intensity physical activity for more than 20 min/day were assessed by 7-day recalls and the responses were divided into 2 groups according to whether they were engaged in at least 3 times/wk.

In the dietary habits questions, the frequency of intake of fruits (not fruit juices), fast food (such as pizza, hamburgers, or ordered chicken), soda, and sugar-sweetened drink (SBB) in the last 7 days was asked. The responses were divided into 2 groups; fruit intake more than 1 time/wk, fast-food intake not less than 1 time/wk, soda consumption not less than 1 time/wk, and sugar-sweetened beverage consumption not less than 1 time/wk. Residential regions were categorized into 2 groups: urban and rural areas. Sedentary duration and sleep duration were calculated as mean hours/week. In the sedentary behavioral time (SBT) questions, SBT was determined by asking the participants how many hours they sit for study and leisure time during a week. SBT for the study was calculated by sitting time in their house, school, and private institute. The SBT for leisure was calculated by time not related to studying (i.e., watching TV, playing video games, and online games). SES was evaluated using a 5-point self-rating scale response. The indicators used in estimating personal SES were classified into 3 groups of low SES (1 points), middle SES (2–3 points), and high SES (4–5 points). Lastly, we divided all subject into 2 age groups as aged 12 to 15 years (most middle school students) and 16 to 18 years (most

high school students).

3. Statistical analysis

R ver. 3.5.1 (The R Foundation for Statistical Computing, Vienna, Austria) was used for statistical analysis. Continuous variables were expressed as the mean±standard deviation and weighted t-test was applied to compare the differences between 2019 and 2020 years. Categorical variables are reported as percentages. The frequencies of each behavioral factor were compared between the age groups, the obesity status groups and the years using weighted chi-square test. A 95% confidence interval (CI) of differences between the years was shown. The Cochran-Armitage trend test was applied to identify significances across the SES. The odds ratio for obesity between the years was calculated using logistic regression. *P*-values of <0.05 were considered significant.

Results

1. Characteristics of the study subjects

Total weighted numbers of participants were 2,683,547 in 2019 and 2,631,888 in 2020. Table 1 shows the demographic characteristics of the subjects according to sex and year. Male composes 51.8%. The mean BMI *z*-score (zBMI) of the total subjects increased from 0.03 to 0.06 (mean BMI, 21.4–21.5 kg/m²) between 2019 and 2020. The mean zBMI of the male subjects increased from 0.12 to 0.22 (BMI, 21.9–22.3 kg/m²), while decreased from -0.07 to -0.11 (BMI, 20.7–20.6 kg/m²) in female. The zBMI marked increased in male aged 12–15 year,

while zBMI slightly decreased in female.

2. Prevalence of obesity and according to age group and SES between 2019 and 2020

Table 2 shows the prevalence of obesity according to age group and SES between 2019 and 2020. The overall prevalence of obesity of the total subjects was 11.0% in 2019 and 12.1% in 2020. This prevalence difference varied by gender (males, 1.8%; females, 0.3%; *P*<0.001), age group (12–15 years, 1.6%; 16–18 years, 0.4%; *P*<0.001), and SES. The prevalence of obesity was increased from 8.1% to 8.4% in female and from 13.8% to 15.6% in male. The prevalence of obesity of male aged 12–15 year increased from 12.5% to 15.2%. Although, prevalence of obesity of low SES was higher than other in both 2019 and 2020, the prevalence of obesity increased significantly in high and middle SES. No significant changes were noted in low SES.

The odds ratio for obesity in 2020 compared with in 2019. The odds ratios (ORs) adjusted for sex, residence region and SES in total and age groups is 1.119 (95% CI, 1.079–1.161). The crude ORs in each sex and age group: female aged 12–15 years; 1.056 (95% CI, 0.967–1.153) versus female aged 16–18; 1.012 (95% CI, 0.929–1.103) versus male aged 12–15 years; 1.296 (95% CI, 1.218–1.378) versus male aged 16–18 years; 1.035 (95% CI, 0.965–1.110).

3. Difference of behavioral factors of the study subjects between 2019 and 2020

Table 3 presents the comparison of behavioral factors by age, sex, and year. Physical activities, fruit intake, consumption of sugar-sweetened beverages showed an overall decrease

Table 1. Demographic characteristics of study participants

Characteristic	2019		2020	
	Female (n=1,254,728)	Male (n=1,358,084)	Female (n=1,234,703)	Male (n=1,334,051)
Age (yr)				
12–15	712,939 (56.8)	765,516 (56.4)	676,355 (54.8)	730,263 (54.7)
16–18	541,789 (43.2)	592,568 (43.6)	558,348 (45.2)	603,788 (45.3)
BMI (kg/m ²)	20.7±3.0	21.9±3.9	20.6±3.1	22.3±3.9
zBMI	-0.07±1.14	0.12±1.31	-0.11±1.18	0.22±1.35
BMI percentiles				
<5	88,466 (7.1)	97,074 (7.1)	104,370 (8.5)	95,144 (7.1)
≥5 to <85	954,470 (76.1)	931,662 (68.6)	920,391 (74.5)	876,380 (65.7)
≥85 to <95	110,135 (8.8)	142,608 (10.5)	106,524 (8.6)	154,783 (11.6)
≥95	101,657 (8.1)	186,740 (13.8)	103,418 (8.4)	207,743 (15.6)
SES				
High	462,090 (36.8)	575,223 (42.4)	466,157 (37.8)	562,851 (42.2)
Middle	635,364 (50.6)	619,321 (45.6)	618,049 (50.1)	604,093 (45.3)
Low	157,275 (12.5)	163,541 (12.0)	150,496 (12.2)	167,107 (12.5)
Residence regions				
Rural area	67,835 (5.4)	76,963 (5.7)	71,040 (5.8)	78,699 (5.9)
Urban area	1,186,893 (94.6)	1,281,121 (94.3)	1,163,663 (94.2)	1,255,352 (94.1)

Values are presented as number (%) or mean±standard deviation. BMI, body mass index; zBMI, BMI *z*-score; SES, socioeconomic status.

Table 2. Comparison of obesity prevalence according to age group and self-reported SES between 2019 and 2020

Variable	2019 (n=2,612,812)	2020 (n=2,568,753)	Difference (95% CI)	P-value
Overall	288,398 (11.0)	311,161 (12.1)	1.1 (0.7 to 1.5)	<0.001
12–15 Years	140,540 (9.5)	155,584 (11.1)	1.6 (1.1 to 2.0)	<0.001
16–18 Years	147,858 (13.0)	155,577 (13.4)	0.4 (-0.3 to 1.0)	0.274
Female	101,657 (8.1)	103,418 (8.4)	0.3 (-0.2 to 0.7)	0.260
12–15 Years	45,076 (6.3)	44,477 (6.6)	0.3 (-0.3 to 0.8)	0.378
16–18 Years	56,582 (10.4)	58,941 (10.6)	0.1 (-0.7 to 0.9)	0.803
High SES	32,799 (7.1)	30,950 (6.6)	-0.5 (-1.2 to 0.3)	0.220
Middle SES	48,948 (7.7)	52,201 (8.4)	0.7 (0.1 to 1.4)	0.028
Low SES	19,910 (12.7)	20,267 (13.5)	0.8 (-0.8 to 2.4)	0.342
Male	186,740 (13.8)	207,743 (15.6)	1.8 (1.2 to 2.4)	<0.001
12–15 Years	95,464 (12.5)	111,107 (15.2)	2.7 (2.0 to 3.5)	<0.001
16–18 Years	91,276 (15.4)	96,636 (16.0)	0.6 (-0.3 to 1.5)	0.211
High SES	76,070 (13.2)	83,874 (14.9)	1.7 (0.8 to 2.6)	<0.001
Middle SES	83,108 (13.4)	93,368 (15.5)	2.0 (1.2 to 2.9)	<0.001
Low SES	27,562 (16.9)	30,501 (18.3)	1.4 (-0.4 to 3.2)	0.129

Values are presented as number (%) using weighted chi-square test.
SES, socioeconomic status; CI, confidence interval.

Table 3. Comparison of behavioral factors classified by age and sex between 2019 and 2020

Variable	2019 (n=2,612,812)	2020 (n=2,568,753)	Difference (95% CI)	P-value
Overall				
Exercise	1,223,777 (46.8)	1,122,236 (43.7)	-3.1 (-3.7 to -2.6)	<0.001
Fruits	1,539,044 (58.9)	1,431,020 (55.7)	-3.2 (-3.8 to -2.6)	<0.001
SSS	2,090,697 (80.0)	1,988,542 (77.4)	-2.6 (-3.1 to -2.1)	<0.001
SSB	2,295,924 (87.9)	2,134,688 (83.1)	-4.8 (-5.2 to -4.4)	<0.001
Fast-food	663,056 (25.4)	650,538 (25.3)	-0.1 (-0.6 to 0.5)	0.849
Stress	2,112,342 (80.8)	2,017,471 (78.5)	-2.3 (-2.8 to -1.8)	<0.001
Sedentary hours	3.3±2.3	4.3±2.8	1.0 (0.9 to 1.0)	<0.001
Mean sleep hours	6.9±1.5	6.8±1.5	-0.1 (-0.1 to -0.0)	<0.001
12–15 Years of age				
Exercise	777,675 (52.6)	675,514 (48.0)	-4.6 (-5.4 to -3.8)	<0.001
Fruits	923,177 (62.4)	832,579 (59.2)	-3.3 (-4.0 to -2.5)	<0.001
SSS	1,178,057 (79.7)	1,071,609 (76.2)	-3.5 (-4.1 to -2.9)	<0.001
SSB	1,293,699 (87.5)	1,140,983 (81.1)	-6.4 (-7.0 to -5.8)	<0.001
Fast-food	365,701 (24.7)	331,774 (23.6)	-1.1 (-1.8 to -0.5)	<0.001
Stress	1,165,239 (78.8)	1,068,217 (75.9)	-2.9 (-3.5 to -2.2)	<0.001
Sedentary hours	3.4±2.3	4.4±2.8	1.0 (0.9 to 1.0)	<0.001
Mean sleep hours	7.4±1.5	7.3±1.5	-0.1 (-0.1 to -0.0)	<0.001
16–18 Years of age				
Exercise	446,102 (39.3)	446,722 (38.4)	-0.9 (-1.8 to 0.0)	0.054
Fruits	615,867 (54.3)	598,441 (51.5)	-2.8 (-3.7 to -1.9)	<0.001
SSS	912,640 (80.5)	916,933 (78.9)	-1.6 (-2.3 to -0.8)	<0.001
SSB	1,002,225 (88.4)	993,705 (85.5)	-2.8 (-3.5 to -2.2)	<0.001
Fast-food	297,355 (26.2)	318,763 (27.4)	1.2 (0.4 to 2.0)	0.004
Stress	947,102 (83.5)	949,254 (81.7)	-1.8 (-2.5 to -1.1)	<0.001
Sedentary hours	3.2±2.2	4.1±2.7	0.9 (0.9 to 1.0)	<0.001
Mean sleep hours	6.3±1.3	6.3±1.3	-0.0 (-0.0 to 0.0)	0.075
Female				
Exercise	363,847 (29.0)	347,206 (28.1)	-0.9 (-1.7 to -0.1)	0.027
Fruits	741,835 (59.1)	684,786 (55.5)	-3.7 (-4.5 to -2.8)	<0.001
SSS	929,971 (74.1)	891,253 (72.2)	-1.9 (-2.7 to -1.2)	<0.001
SSB	1,091,833 (87.0)	1,001,537 (81.1)	-5.9 (-6.5 to -5.3)	<0.001
Fast-food	292,382 (23.3)	290,752 (23.5)	0.2 (-0.5 to 1.0)	0.512

(Continued)

Table 3. Comparison of behavioral factors classified by age and sex between 2019 and 2020 (continued)

Variable	2019 (n=2,612,812)	2020 (n=2,568,753)	Difference (95% CI)	P-value
Stress	1,096,271 (87.4)	1,043,705 (84.5)	-2.8 (-3.4 to -2.2)	<0.001
Sedentary hours	3.3±2.2	4.3±2.8	1.0 (0.9 to 1.0)	<0.001
Mean sleep hours	6.7±1.5	6.6±1.5	-0.1 (-0.1 to -0.0)	<0.001
12–15 Years of age				
Exercise	252,867 (35.5)	228,001 (33.7)	-1.8 (-2.8 to -0.7)	0.001
Fruits	445,923 (62.5)	396,710 (58.7)	-3.9 (-5.0 to -2.8)	<0.001
SSS	529,072 (74.2)	477,857 (70.7)	-3.6 (-4.6 to -2.6)	<0.001
SSB	620,101 (87.0)	536,217 (79.3)	-7.7 (-8.5 to -6.9)	<0.001
Fast-food	163,864 (23.0)	148,537 (22.0)	-1.0 (-2.0 to -0.1)	0.033
Stress	609,626 (85.5)	556,217 (82.2)	-3.3 (-4.1 to -2.4)	<0.001
Sedentary hours	3.4±2.3	4.4±2.8	1.0 (0.9 to 1.0)	<0.001
Mean sleep hours	7.1±1.4	7.1±1.5	-0.0 (-0.1 to -0.0)	0.009
16–18 Years of age				
Exercise	81,022 (15.0)	86,532 (15.5)	0.5 (-0.4 to 1.5)	0.273
Fruits	295,912 (54.6)	288,076 (51.6)	-3.0 (-4.4 to -1.7)	<0.001
SSS	400,898 (74.0)	413,396 (74.0)	0.0 (-1.1 to 1.2)	0.953
SSB	471,733 (87.1)	465,320 (83.3)	-3.7 (-4.7 to -2.8)	<0.001
Fast-food	128,518 (23.7)	142,214 (25.5)	1.7 (0.6 to 2.9)	0.003
Stress	486,644 (89.8)	487,488 (87.3)	-2.5 (-3.4 to -1.7)	<0.001
Sedentary hours	3.2±2.0	4.1±2.7	1.0 (0.9 to 1.0)	<0.001
Mean sleep hours	6.1±1.3	6.1±1.3	-0.0 (-0.1 to 0.0)	0.290
Male				
Exercise	859,930 (63.3)	775,030 (58.1)	-5.2 (-6.0 to -4.4)	<0.001
Fruits	797,209 (58.7)	746,234 (55.9)	-2.8 (-3.6 to -1.9)	<0.001
SSS	1,160,726 (85.5)	1,097,289 (82.3)	-3.2 (-3.8 to -2.6)	<0.001
SSB	1,204,090 (88.7)	1,133,151 (84.9)	-3.7 (-4.3 to -3.2)	<0.001
Fast-food	370,674 (27.3)	359,786 (27.0)	-0.3 (-1.1 to 0.4)	0.390
Stress	1,016,071 (74.8)	973,766 (73.0)	-1.8 (-2.5 to -1.1)	<0.001
Sedentary hours	3.3±2.3	4.2±2.8	0.9 (0.9 to 1.0)	<0.001
Mean sleep hours	7.1±1.5	7.0±1.5	-0.1 (-0.1 to -0.0)	<0.001
12–15 Years of age				
Exercise	524,808 (68.6)	447,513 (61.3)	-7.3 (-8.3 to -6.2)	<0.001
Fruits	477,254 (62.3)	435,869 (59.7)	-2.7 (-3.7 to -1.6)	<0.001
SSS	648,984 (84.8)	593,753 (81.3)	-3.5 (-4.3 to -2.7)	<0.001
SSB	673,598 (88.0)	604,766 (82.8)	-5.2 (-5.9 to -4.4)	<0.001
Fast-food	201,837 (26.4)	183,237 (25.1)	-1.3 (-2.2 to -0.3)	0.008
Stress	555,613 (72.6)	512,000 (70.1)	-2.5 (-3.4 to -1.5)	<0.001
Sedentary hours	3.4±2.3	4.4±2.8	1.0 (0.9 to 1.0)	<0.001
Mean sleep hours	7.6±1.5	7.6±1.4	-0.1 (-0.1 to -0.0)	<0.001
16–18 Years of age				
Exercise	335,122 (56.6)	327,517 (54.2)	-2.3 (-3.6 to -1.0)	<0.001
Fruits	319,956 (54.0)	310,365 (51.4)	-2.6 (-3.9 to -1.3)	<0.001
SSS	511,742 (86.4)	503,536 (83.4)	-3.0 (-3.9 to -2.0)	<0.001
SSB	530,492 (89.5)	528,385 (87.5)	-2.0 (-2.8 to -1.2)	<0.001
Fast-food	168,837 (28.5)	176,549 (29.2)	0.7 (-0.4 to 1.9)	0.211
Stress	460,458 (77.7)	461,766 (76.5)	-1.2 (-2.3 to -0.1)	0.026
Sedentary hours	3.2±2.3	4.1±2.7	0.9 (0.8 to 0.9)	<0.001
Mean sleep hours	6.5±1.3	6.4±1.3	-0.0 (-0.1 to 0.0)	0.129

Values are presented as number (%) using weighted chi-square test or mean±standard deviation using weighted *t*-test. CI, confidence interval; SSS, sugar-sweetened soda; SSB, sugar-sweetened beverages.

between the years. Stress was also decreased overall during the years. Fast-food consumption was decreased in the 12–15 years age group and increased in the 16–18 years age group. Sleep duration decreased slightly in 12–15 years of ages and no significant changes were observed in 16–18 years during the period. However, nonstudy sedentary time marked increased from 3.3±2.3 hr/day to 4.3±2.8 hr/day between the years.

4. Difference of physical activities of the study subjects between 2019 and 2020

The comparison of physical activities (moderate-intensity aerobic physical activity and vigorous-intensity physical activity) in nonobese and obese between 2019 and 2020 is depicted in Fig. 1A and B (Supplementary Tables 1, 2). Moderate-intensity aerobic physical activity for more than 60 min/day at least 3

times/wk decreased from 46.1% to 41.1% in male (nonobese, 47.0%–41.5%; obese, 41.2%–39.8%; all $P<0.001$), while slight decreased from 21.2% to 20.8% in female (nonobese, 20.9%–20.4%; obese, 21.9%–23.0%; all $P<0.001$). Vigorous-intensity physical activity decreased in all male (12–15 years, 50.0%–40.5%; 16–18 years, 38.2%–34.5%; all $P<0.001$) and female aged 12–15 years (21.9%–19.6%, $P<0.001$), while slightly changed in female aged 16–18 years (12.8%–12.6%, $P=0.003$). In male aged 12–15 years showed marked decrease moderate-intensity aerobic physical activity and vigorous-intensity physical activity between 2019 and 2020. Although, subjects with low SES showed a tendency of less frequent physical activity in both years, the decrease of physical activity frequency was observed markedly in male high and middle SES group when compared between 2019 and 2020 (Supplementary Table 3).

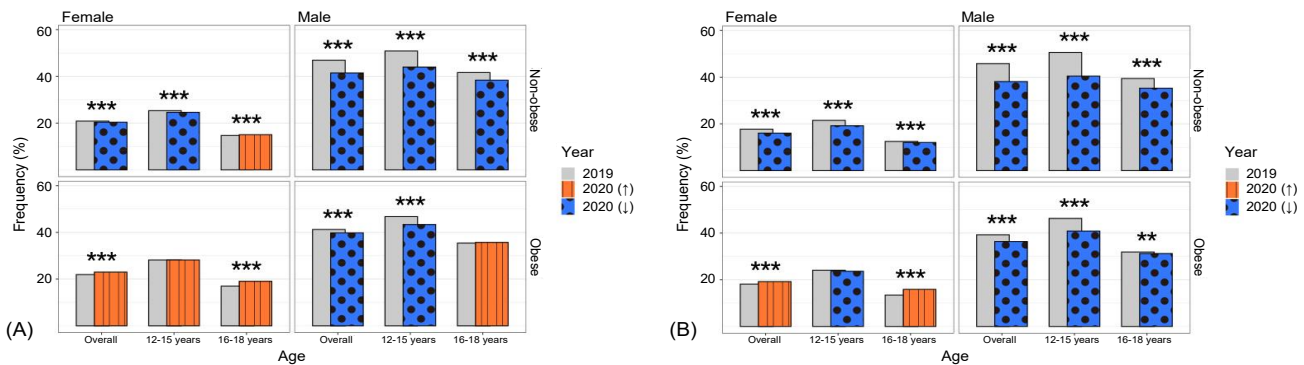


Fig. 1. (A) Moderate-intensity aerobic physical activity for more than 60 min/day at least 3 times/wk. (B) Vigorous-intensity physical activity for more than 20 min/day at least 3 times/wk. ^{*} $P<0.01$ and ^{***} $P<0.001$, using weighted chi-square tests, respectively.

Table 4. Comparison of lifestyle behaviors between obese and normal weight subjects

Variable	Obesity (n=4,488)	Normal weight (n=39,428)	Difference (95% CI)	P-value
Female				
Exercise	1,017 (22.7)	8,497 (21.6)	1.1 (-0.2 to 2.4)	0.091
Fruits	2,244 (50.0)	22,749 (57.7)	-7.7 (-9.3 to -6.1)	<0.001
SSS	3,379 (75.3)	28,979 (73.5)	1.8 (0.4 to 3.1)	0.010
SSB	3,745 (83.4)	33,283 (84.4)	-1.0 (-2.1 to 0.2)	0.095
Fast-food	1,012 (22.5)	9,153 (23.2)	-0.7 (-2.0 to 0.6)	0.326
Stress	3,964 (88.3)	33,769 (85.6)	2.7 (1.7 to 3.7)	<0.001
Sedentary hours	4.0±2.7	3.8±2.5	-0.3 (-0.3 to -0.2)	<0.001
Mean sleep hours	6.6±1.5	6.8±1.5	0.2 (0.1 to 0.2)	<0.001
Male				
Exercise	3,523 (41.6)	17,675 (46.5)	-4.9 (-6.1 to -3.7)	<0.001
Fruits	4,580 (54.0)	21,911 (57.6)	-3.6 (-4.7 to -2.4)	<0.001
SSS	7,051 (83.2)	32,031 (84.2)	-1.0 (-1.9 to -0.1)	0.022
SSB	7,297 (86.1)	33,175 (87.2)	-1.1 (-1.9 to -0.3)	0.006
Fast-food	2,040 (24.1)	10,332 (27.2)	-3.1 (-4.1 to -2.1)	<0.001
Stress	6,411 (75.6)	27,745 (72.9)	2.7 (1.7 to 3.7)	<0.001
Sedentary hours	4.1±2.8	3.7±2.5	-0.4 (-0.4 to -0.3)	<0.001
Mean sleep hours	7.0±1.5	7.2±1.5	0.2 (0.1 to 0.2)	<0.001

Values are presented as number (%) or mean±standard deviation using unweighted data. CI, confidence interval; SSS, sugar-sweetened soda; SSB, sugar-sweetened beverages.

5. Difference of behavioral factors between obese and normal weight subjects

Comparisons of behavioral factors between obese and normal weight subjects are presented in Table 4. Obese boys and men were found to exercise less compared to those with normal weight. Fruit intake was lower in obese subjects. Fast-food consumption was lower in subjects with obesity. In obese subjects, nonstudy sedentary time was longer and sleep duration was shorter than those with normal weight.

Discussion

In this study, we found that the obesity prevalence of adolescents aged 12–18 years in 2020 (post-COVID-19) increased to 12.1% compared with 11.1% in 2019 (pre-COVID-19) using data of the Korea Youth Risk Behavior Web-based Survey. We also found that main increase of obesity adolescents was middle school boys and with high and middle SES. In this group, we identified decreased physical activity and increased sedentary time played major role.

This study demonstrated difference in obesity prevalence, physical activity, diet, stress, and sleep time that occurred before and after the COVID-19 pandemic among a representative sample of Korean adolescents. Our findings are in line with several studies on COVID-19-related weight changes in children and adolescents.^{19,22} In Korean adolescents the overall BMI increased from 21.4 kg/m² in 2019 to 21.5 kg/m² in 2020. While, there was gender and age group difference; male adolescents aged 12–15 years only increased the total BMI from 21.3 kg/m² in 2019 to 21.8 kg/m² in 2020, male adolescents aged 16–18 years showed no change, female adolescents showed slight decrease.

One interesting finding in this study is, the overall obesity increased in all age group and both sexes, however, marked increased prevalence of obesity was shown male adolescents aged 12–15 years (mainly middle school boys). In USA MPDHnet study including 46,151 participants aged 2–20 years, they found greater increase obesity prevalence in boys, younger age, and some race comparing 2019 with 2020.¹⁹ In China COINLICS study including 10,082 participants aged 19.8±2.3 years, the youths' average BMI increased from 21.8 to 22.1 kg/m², with obesity increasing from 10.5% to 12.6%.²⁰ They also demonstrated younger age and male showed greater increase. In Germany, 3-month change in zBMI was lower in adolescents aged 12–18 years compared younger children but not between sexes.¹² In addition, several other COVID-related studies also reported a remarkable weight gain in elementary school children or children aged 7–12 years¹⁵; Therefore, our findings are in line with other studies. Korean male aged 12–15 years is rapid pubertal growth phase, while others are late puberty and most reached final height heights and relative stable weight.²³ In Korean female, the mean age of menarche is 12.6 years and most reached their final height.²⁴ In our study, the ORs of

adolescents' obesity in 2020 compared to 2019 is 1.119 (95% CI, 1.079–1.161). The ORs of male aged 12–15 years was 1.296 (95% CI, 1.218–1.378). Thus, the odds ratio for obesity of Korean adolescents before and during the COVID-19 pandemic increased by 11.9%. The main portion of increased prevalence was male aged 12–15 years (29.6%).

The other interesting finding is that only moderate-/vigorous-intensity physical activity and average sedentary time showed marked difference especially in middle school boys before and after COVID-19. Most studies demonstrated the lockdown to prevent the spread of COVID-19, resulted in tremendous changes in lifestyle, including diet patterns, physical activity, and sleep patterns. Sedentary behavior including longer screen time along with physical inactivity is associated with a decrease in the basal metabolic correction factor by 10% to 50%.²⁵ Decrease in aerobic exercise induces cravings for high-calorie foods and higher levels of physical activity reduce BMI.^{26,27} For every 1 hour of moderate-to-vigorous activity might decrease the risk of developing obesity by 10%.²⁸ In the females aged 16–18 years, the prevalence of obesity increased the least (Table 2) and the increase of physical activity frequencies was the greatest (Supplementary Tables 1, 2). This group seemed to use spare time most actively in the health behavior change of this study population. Thus, education on ideal weight and proper weight control may contribute to improving the prevalence of obesity.

The lifestyle changes inevitably lead to weight gain during the lockdown.²⁹ In Korea like other countries, shutdown of sports facilities, reduced physical activity including school sports, and excess screen time including online classes affects lifestyle changes of adolescents inevitably lead to weight gain. However, the unhealthy eating including soda, SBB, and fast-food did not increased or even decreased. That might be due to adolescents at home are more supervised by their parents in Korea. Instead of eating fast food or junk food with friends in school and after school, the adolescents obviously ate most meals at home with their parents. Although, COVID-19-related decrease in physical activity and sedentary behavior has already been shown in most studies,^{7,9,30,31} there are mixed results concerning dietary behavior.^{7,30,32} Some studies described increased total consumption and unhealthy binge eating, while other studies increased adherence to a healthy diet, homemade meals and increased eating with friends or family.²⁹ The diet patterns change during COVID-19 differ according to country, culture, economy, and nutrition education along with age, sex, and body weight status. A slight increase of obesity prevalence was observed in groups other than low SES, however, no significant changes of the prevalence was observed in low SES group (Table 2). The relationship of SES to child obesity prevalence is observed to have a negative or a positive association according to the socioeconomic development level of a country being studied.^{33,34} The prevalence of obesity was highest in the low SES group in this study population. Therefore, it is conceivable that the obesity-related risk factors, which began to influence the prevalence of obesity in the high and middle SES groups after the pandemic, were already influencing the prevalence in

low SES group.

The strengths of this study include a large nationally representative sample of the Korean adolescent population with the use of same protocols before and after COVID-19. However, this study has several limitations. First, the survey was conducted through self-reporting. Thus, the data, especially weight, may lead to an underestimation.¹⁸⁾ Second, this study subjects was adolescents aged 12–18 years, investigation of younger age including elementary school and preschool children should be needed. Finally, the variable of KYRWB data was qualitative rather than quantitative for diet variables and SES, thus its applicability to this context and the possibility of using alternative surveys are needed.

In conclusion, this study confirms that the environment created by the COVID-19 resulted in increased obesity prevalence in Korean adolescents aged 12–18 years. Korean middle school boys were most affected subjects by decreasing physical activity due to COVID-19 lockdown and school shutdown. This study presented unique strengths in the targeted population promptly for drawing strong conclusions. Health professionals and parents should aware physical activity is important for preventing obesity in adolescent period. Governments along with school administrators must develop social and in-school physical activity programs to prevent obesity from a long-term perspective.

Ethical statement

The Research Ethics Committee of the Korea Centers for Disease Control approved the study protocol (No: 2022-05-001).

Notes

Supplementary material: Supplementary Tables 1–3 can be found via <https://doi.org/10.6065/apem.2244116.058>.

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