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Changes in obesity and lifestyle behaviours during the COVID-19 pandemic in Chinese adolescents: A longitudinal analysis from 2019 to 2020

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Summary

Background: Since December 2019, the coronavirus disease 2019 (COVID-19) has become a global pandemic. Currently, the COVID-19 pandemic is still ongoing. What changes have taken place in the obesity and obesity-related lifestyle behaviours of adolescents during the first year of the COVID-19 pandemic?

Objective: This study aims at analysing the changes in obesity and lifestyle behaviours of Chinese adolescents before and 1 year after the outbreak of the COVID-19 pandemic, providing evidence for the global strategies to respond to the impact of the COVID-19 pandemic on adolescent obesity.

Methods: Physical examinations and student health and influencing factors questionnaires were conducted among 6047 adolescents aged 11–16 years by health professionals in Shanghai, China, before the COVID-19 pandemic (September–November of 2019) and 1 year after the outbreak of the COVID-19 pandemic (September–November of 2020). Paired χ^2 tests, paired *t*-tests or Wilcoxon signed-rank test was used to evaluate the changes in the obesity prevalence, BMI and lifestyle behaviours from 2019 to 2020.

Results: 1 year after the outbreak of the COVID-19 pandemic, the obesity prevalence of Chinese adolescents rose from 14.2% to 15.4% ($p < 0.01$), mainly because of the increase in boys. And the average BMI increased from 20.3 to 21.2 kg/m^2 ($p < 0.01$). Their lifestyle behaviours have also significantly changed. The mobile screen time increased from 0.25–1.50 h/day to 0.33–2.00 h/day ($p < 0.01$). The proportion of adolescents who participated in MVPA for ≥60 min/day on all 7 days during the past week dropped from 14.4% to 11.7% ($p < 0.01$). The generalized estimation equation analysis indicated that adolescents who participated in MVPA for ≥60 min/day on all 7 days had a lower likelihood of having obesity. Boys with

List of Abbreviations: COVID-19, coronavirus disease 2019; BMI, body mass index; MVPA, moderate-to-vigorous physical activity.

Dongling Yang and Chunyan Luo are contributed equally to this work.

computer time ≥2 h/day and girls with mobile screen time ≥2 h/day or TV time ≥2 h/day had a higher likelihood of having obesity.

Conclusion: This study found that 1 year after the outbreak of the COVID-19 pandemic, the BMI and obesity prevalence of Chinese adolescents increased and obesity-related lifestyle behaviours have also changed.

KEYWORDS
adolescents, COVID-19, lifestyle behaviours, longitudinal analysis, obesity

1 | INTRODUCTION

Obesity is a global public health challenge.[1] In 2016, over 340 million children and adolescents aged 5–19 years worldwide with overweight or obese.[2] In China, the prevalence of overweight and obese children and adolescents aged 7–18 years was 20.5% in 2014.[3] Obesity in childhood and adolescence is associated with adverse health consequences throughout the life course.[4,5] Many efforts have been made in the past[6–8] to curb the global obesity epidemic.

However, since December 2019, the coronavirus disease 2019 (COVID-19) has become a global pandemic. To contain the spread of COVID-19, many governments have undertaken uncompromising measures, including home quarantine, lockdown, and school closures. In Shanghai, China, after experiencing an extended winter vacation until the end of February 2020, all of the primary and secondary school students began to attend classes online in March and did not start returning to school until mid-May. As a direct consequence, children's lifestyles, such as physical activity behaviours, screen behaviours, and dietary behaviours, might have been negatively affected,[9–11] and this has been associated with childhood obesity.[12]

Some studies have investigated the impact of the COVID-19 lockdown on lifestyle behaviours and obesity status among children.[13–15] An Italian study[13] determined that children with obesity had decreased their exercise time and increased their screen and sleeping time during the COVID-19 lockdown. A Chinese study of youths found that, before and after COVID-19 lockdown, the prevalence of overweight/obesity and obesity increased. In addition, significant decreases were seen in the frequency of engaging in physical activity, while significant increases were observed in the average sedentary time, sleeping time, and screen time.[14] A French study that included 6491 children also showed the deleterious effects of confinement caused by the lockdown on physical activity and sedentary behaviours.[15]

Now the COVID lockdown has been cancelled in most countries, but the COVID-19 pandemic is still ongoing. In the first year of the COVID-19 pandemic, children and adolescents in China have gone through home isolation and online classes, and then gradually returned to normal study life. From the end of 2019 to the end of 2020, that is, before the outbreak of the COVID-19 pandemic and 1 year after the outbreak of the COVID-19 pandemic, what changes have taken place in the obesity and obesity-related lifestyle behaviours of children and adolescents? Therefore, this study aims at analysing the changes in obesity and lifestyle behaviours of Chinese adolescents before and 1 year after the outbreak of the COVID-19 pandemic, providing evidence for the global strategies and policies to respond to the impact of the COVID-19 pandemic on adolescent obesity.

2 | METHOD

2.1 | Study design and participants

Data were collected from the Surveillance of Students' Common Diseases and Health Influencing Factors conducted in Shanghai, China. The surveillance was conducted in all 16 districts of Shanghai during September and November of 2019 and 2020. According to the level of social and economic development, 16 districts were divided into seven urban areas (district of Huangpu, Xuhui, Jing'an, Changning, Putuo, Hongkou, and Yangpu) and nine suburbs (district of Pudong, Jinshan, Minhang, Fengxian, Songjiang, Qingpu, Jiading, Baoshan, and Chongming).

A multi-stage stratified cluster sampling method was used, and two junior high schools from each district were randomly selected, with a total of 32 junior high schools selected. Two to three classes from each grade (grades 6–9) of each school were randomly selected, and all of the students in the selected classes participated in the survey. Figure 1 shows the flow chart of the participants' selection and data extraction and matching. A total of 6047 junior high school students participated in physical examinations and a questionnaire survey for 2 years was included in this study. This study was approved by the Ethics Committee of the Shanghai Municipal Center for Disease Control and Prevention.

2.2 | Physical examination

Each district established a physical examination team composed of professionals, including professional technicians from the centres for disease control and prevention and community health service in each district. The physical examination team entered the schools after a unified training program. Heights and weights were measured by two professional technicians following a uniform procedure: one for the measurement and one for the recording. The standing height was measured to the nearest 0.1 cm using a stadiometer, and weight

was measured to the nearest 0.1 kg using a digital scale. The digital scale was Locosc XK3150 manufactured by Ningbo Langke Precision Technology Limited Company, and the stadiometer was TZG manufactured by Wuxi Weigher Factory Limited Company. Boys and girls were measured separately, and students were required to remove their shoes and only wear underwear during the measurements. Each student's physical examination form had a unique identification code. Prevention and control measures for COVID-19 had been added to the 2020 survey, including wearing masks, maintaining distances, and disinfecting the instruments after each student's physical examination.

The definitions of overweight and obesity were based on the body mass index (BMI), which was calculated as weight (in kilograms) divided by the square of height (in meters). The age- and sex-specific BMI cut-offs defined by the World Health Organization (WHO) were chosen to assess the weight status of each individual.[16] A *Z*-score of the BMI greater than one was defined as overweight, and a *Z*-score greater than two was defined as obesity.[16]

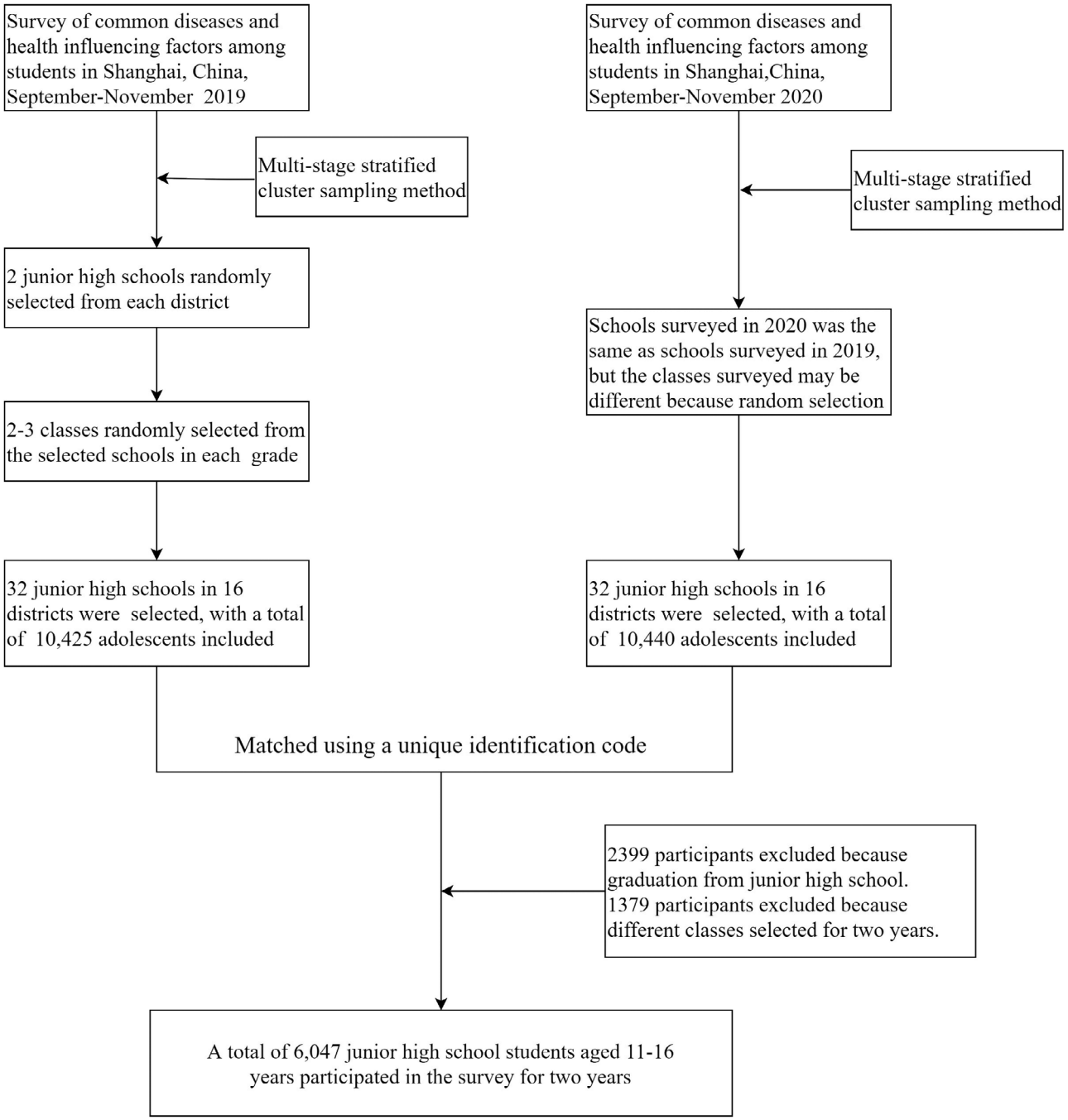

FIGURE 1 Flow chart of the participants' selection and data extraction and matching from the surveillance of the Students' Common Diseases and Health Influencing Factors in Shanghai, China, 2019–2020

2.3 | Questionnaire survey

The survey was conducted using the "Student Health and Influencing Factors questionnaire" compiled by the project of National Students' Common Diseases and Health Influencing Factors. On the day of the investigation, after a brief explanation, the questionnaires were completed by the students themselves. The investigators collected the questionnaires on the spot and checked the accuracy and completeness of the questionnaires simultaneously. The questionnaires collected the students' gender, age, self-recognized household income, screen behaviours, physical activity behaviours, sleep duration, and dietary behaviours. Household income was obtained through the following questions "What do you think of your family's financial situation?" The options were "very good, good, general, poor, or very poor." The question wording and details for lifestyle behaviour variables are shown in Table 1. Most of the variables are categorical variables, not continuous variables. This study only analyses dietary behaviours related to adolescent obesity, including the frequency of intake of sugar-sweetened beverages, fresh vegetables, fruits, and breakfast.

2.4 | Quality control

All of the investigators took up their posts after the uniform training, and all of the surveying personnel came from professional institutions. All of the instruments were calibrated before the measurements. The physical examinations and questionnaire surveys in each district were supervised by the Shanghai Municipal Center for Disease Control and Prevention. Quality control personnel were established in each district to perform the quality control. On the day of the survey, the data of the physical examinations and questionnaires were checked for

TABLE 1 Question wording and details for lifestyle behaviour variables—Surveillance of Students' Common Diseases and Health Influencing Factors, Shanghai, China, 2019–2020

Variable	Question	Response options	Coding for analysis
Screen behaviours			
TV time ≥2 h/day	During the past week, how long did you watch TV on average every day?	I have not watched it, <1 h, 1–2 (excluding 2) h, 2–3 (excluding 3) h, 3–4 (excluding 4) h, or ≥ 4 h	≥2 h/day versus <2 h/day
Computer time ≥2 h/day	During the past week, how long did you usually play computer every day?	I have not played it, <1 h, 1–2 (excluding 2) h, 2–3 (excluding 3) h, 3–4 (excluding 4) h, or ≥ 4 h	≥2 h/day versus <2 h/day
Mobile screen time ≥2 h/day	During the past week, how long did you spend on mobile electronic devices on average every day (including mobile phones, tablets, etc.)?	I have never used it, or an average of ____ h ___ min/day	≥2 h/day versus <2 h/day
Mobile screen time, h/day (P_{25}–P_{75})			Numerical variables
Physical activities behaviours			
MVPA ≥ 60 min/day on all 7 days	During the past week, how many days have you been able to do at least 60 min of MVPA every day (accumulatively)? (MVPA refers to exercises that make you breathless or increase your heartbeat. Such as running, basketball, football, swimming, aerobics in the gym, lifting heavy objects, etc.)	0 days, 1 day, 2 days, 3 days, 4 days, 5 days, 6 days, or 7 days	7 days versus <7 days
Days of MVPA≥60 min/day			Numerical variables
Outdoor activities ≥2 h/day	During the past week, how much time did you spend outdoors during the day (accumulatively)?	<1 h, 1–2 (excluding 2) h, 2–3 (excluding 3) h, ≥3 h, or I do not know	≥2 h/day versus <2 h/day
Sleep duration			
Sleep duration, h/day	During the past week, how long did you sleep on average every day?	____h____min	Numerical variables
Dietary behaviours			
Sugar-sweetened beverage ≥1 time/day	During the past week, how many times did you drink sugar-sweetened beverages?	Never drink, <1 time/day, or ≥ 1 time/day	≥1 time/day versus <1 time/day
Fresh fruit ≤1 time/day	During the past week, how many times did you eat fresh fruits (not including canned fruits)?	Never eat, <1 time/day, 1 time/day, or ≥2 times/day	≤1 time/day versus ≥2 times/day
Vegetables ≤1 time/day	During the past week, how many times did you eat vegetables? (Both raw and cooked)	Never eat, <1 time/day, 1 time/day, or ≥2 times/day	≤1 time/day versus ≥2 times/day
Did not eat breakfast on all 7 days	During the past week, did you eat breakfast every day?	Every day, sometimes, or never eat	<7 days versus 7 days

TABLE 2 Characteristics of 6047 participants in Shanghai, China, 2019

	Total	Boys	Girls
Total	6047	3093 (51.1)	2954 (48.9)
District			
Urban	2706 (44.8)	1449 (46.8)	1257 (42.6)
Rural	3341 (55.3)	1644 (53.2)	1697 (57.4)
Age			
11~	1597 (26.4)	787 (25.4)	810 (27.4)
12~	1993 (33.0)	1060 (34.3)	933 (31.6)
13~	2043 (33.8)	1010 (32.7)	1033 (35.0)
14–16	414 (6.9)	236 (7.6)	178 (6.0)
Household income			
Good	2856 (47.3)	1463(47.4)	1393 (47.2)
General	2886 (47.8)	1462 (47.3)	1424 (48.3)
Poor	298 (5.0)	164 (5.3)	134 (4.5)
Height, cm (SD)	158.6 (8.7)	160.3 (9.9)	156.7 (7.0)
Weight, kg (SD)	51.4 (13.3)	53.9 (14.5)	48.7 (11.3)
BMI, kg/m^2 (SD)	20.3 (4.1)	20.8 (4.3)	19.7 (3.9)
Overweight prevalence, % (95% CI)	22.2 (21.2–23.3)	25.2 (23.6–26.7)	19.2 (17.8–20.6)
Obesity prevalence, % (95%CI)	14.2 (13.3–15.0)	20.9 (19.4–22.3)	7.1 (6.2–8.1)

Note: Data are *n* (%), mean (SD), or prevalence (95% CI).

TABLE 3 Obesity prevalence and incidence of adolescents in Shanghai, China, 2019–2020

	Prevalence of obesity				Incidence of obesity		
	N	2019	2020	*p**	*N*[a]	*n* (%)	*p***
Total	6047	856 (14.2)	929 (15.4)	<0.01	5191	224 (4.3)	/
District							0.60
Urban	2706	408 (15.1)	428 (15.8)	<0.01	2298	103 (4.5)	
Rural	3341	448 (13.4)	501 (15.0)	<0.01	2893	121 (4.2)	
Gender							<0.01
Boys	3093	645 (20.9)	715 (23.1)	<0.01	2448	169 (6.9)	
Girls	2954	211 (7.1)	214 (7.2)	0.29	2743	55 (2.0)	
Age							0.12
11~	1597	257 (16.1)	268 (16.8)	0.21	1340	52 (3.9)	
12~	1993	293 (14.7)	317 (15.9)	0.02	1700	80 (4.7)	
13~	2043	256 (12.5)	296 (14.5)	<0.01	1787	84 (4.7)	
14–16	414	50 (12.1)	48 (11.6)	0.18	364	8 (2.2)	
Household income							0.77
Good	2856	394 (13.8)	422 (14.8)	0.01	2462	105 (4.3)	
General	2886	413 (14.3)	454 (15.7)	<0.01	2473	106 (4.3)	
Poor	298	49 (16.4)	53 (17.8)	0.86	249	13 (5.2)	

[a]*N* is the total number of participants with no obesity in 2019.
**p* value for paired chi-square test of changes in obesity prevalence in 2019–2020.
***p* value for chi-square test of differences in obesity incidence between subgroups.

whether there existed omissions or errors and whether the handwriting on each survey was clear. In addition, 5% of students were randomly selected every day to retest their heights and weights, and the problems found were corrected at that time.

2.5 | Statistical analysis

EpiData3.1 software was used for the data entry. The data were cleaned and merged into a final database. SAS9.3 software was used

for the statistical analysis. The normal numerical variables were expressed by mean (SD), and the non-normal numerical variables were expressed by median (P_{25}–P_{75}). The categorical variables were expressed using *n* (%) or prevalence (95% CI). Paired χ^2 tests, paired *t*-tests or Wilcoxon signed-rank test was used to compare changes in the obesity prevalence, BMI, screen behaviours, physical activity behaviours, sleep duration and dietary behaviours from 2019 to 2020. χ^2 tests, *t*-tests or Wilcoxon rank-sum test was used to compare the differences in the obesity prevalence, obesity incidence, screen behaviours, physical activity behaviours, sleep duration and dietary behaviours between different subgroups. Because the data are 2-year longitudinal data, generalized estimation equation analysis was used to analyse the influencing factors of the obesity prevalence of junior high school students from 2019 to 2020. The dependent variable was the obesity prevalence of students from 2019 to 2020. The independent variables included gender, age, region, household income, screen behaviours, physical activity behaviours, sleep duration, and dietary behaviours from 2019 to 2020 (see Table 1 for detailed variable information). $p < 0.05$ indicated that the difference was statistically significant.

3 | RESULTS

3.1 | Characteristics of participants

Table 2 shows the characteristics of participants in this study in 2019. A total of 6047 junior high school students aged 11–16 years participated in physical examinations and questionnaire surveys for 2 years. Among them, 3093 (51.1%) were boys and 2954 (48.9%) were girls, with an average age of 12.7 years. The average BMI of participants in 2019 was 20.3 kg/m^2, of which the boys were 20.8 kg/m^2 and the girls were 19.7 kg/m^2. The prevalence of obesity was 14.2%, and boys (20.9%) were higher than girls (7.1%).

3.2 | Changes in the obesity prevalence and incidence from 2019 to 2020

The obesity prevalence among the 6047 junior high school students in Shanghai, China, rose from 14.2% in 2019 to 15.4% in 2020 ($p < 0.01$), of which boys increased from 20.9% in 2019 to 23.1% in 2020 ($p < 0.01$), and girls did not increase (7.1% vs. 7.2%, $p = 0.29$). In addition, from 2019 to 2020, the prevalence of obesity in urban and rural areas in 12- and 13-year-old groups and adolescents with good and general household income also increased significantly (see Table 3).

Table 3 also showed the incidence of obesity in 2019–2020 was 4.3% and that of boys was 6.9%, which was higher than the 2.0% of girls ($p < 0.01$). There was no statistical difference between the obesity incidence of urban and rural areas, different ages, and different household incomes.

Taking BMI as the analysis variable, the average BMI of participants increased from 20.3 kg/m^2 in 2019 to 21.2 kg/m^2 in 2020. From 2019 to 2020, the average BMI of adolescents in different districts, different age groups, and different household incomes all have a significant increase ($p < 0.01$). The increase in BMI of boys was greater than that of girls, and the younger the age groups, the greater the increase in BMI (see Table 4 and Figure 2).

TABLE 4 BMI of adolescents in Shanghai, China, 2019–2020, kg/m^2

	N	2019	2020	$\Delta_{2020-2019}$[a]	*p**
Total	6047	20.3 (4.1)	21.2 (4.4)	0.9 (0.2–1.8)	/
District					0.27
Urban	2706	20.3 (4.2)	21.3 (4.2)	1.0 (0.2–1.8)	
Rural	3341	20.2 (4.1)	21.2 (4.5)	0.9 (0.2–1.8)	
Gender					<0.01
Boys	3093	20.8 (4.3)	21.9 (4.7)	1.0 (0.2–2.0)	
Girls	2954	19.7 (3.9)	20.6 (3.9)	0.9 (0.2–1.6)	
Age					<0.01
11	1597	19.6 (3.8)	20.6 (4.0)	1.1 (0.4–1.9)	
12	1993	20.2 (4.2)	21.2 (4.3)	1.0 (0.2–1.9)	
13	2043	20.7 (4.2)	21.7 (4.5)	0.8 (0.1–1.7)	
14–16	414	21.0 (4.4)	21.7 (5.0)	0.7 (0.0–1.6)	
Household income					0.45
Good	2856	20.2 (4.0)	21.1 (4.2)	0.9 (0.2–1.8)	
General	2886	20.3 (4.2)	21.4 (4.5)	1.0 (0.2–1.8)	
Poor	298	20.6 (4.1)	21.6 (4.4)	0.9 (0.2–2.0)	

Note: Data are mean (SD) or median (P_{25}–P_{75}).
Abbreviation: BMI, body mass index.
[a]Differences in BMI between 2020 and 2019.
**p* value for the Wilcoxon test of differences between subgroups.

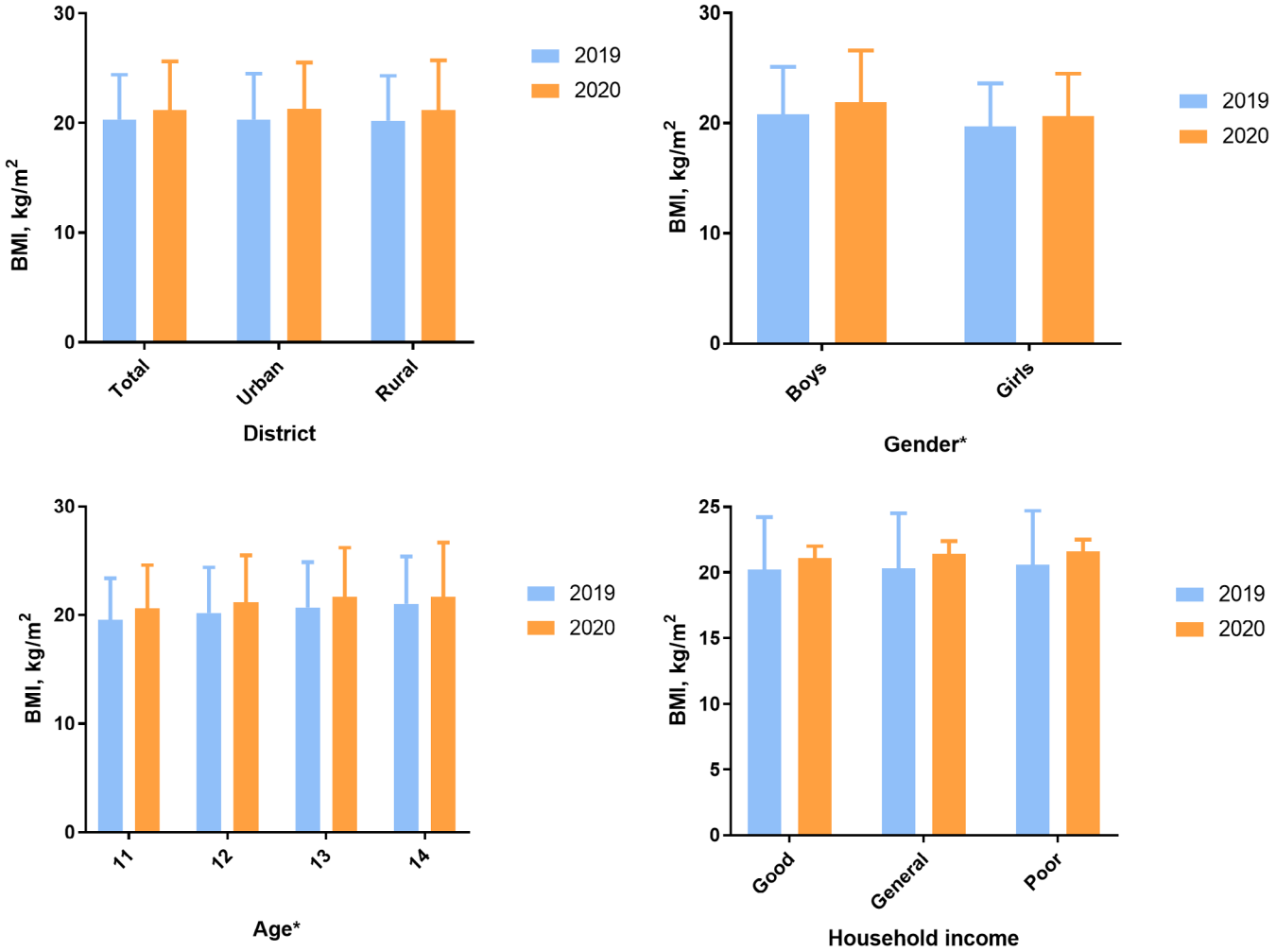

FIGURE 2 Changes in BMI of Chinese adolescents with different characteristics from 2019 to 2020. From 2019 to 2020, the average BMI of adolescents in overall, different districts, different age groups, and different household incomes all have a significant increase ($p < 0.01$). The increase in BMI of boys was greater than that of girls, and the younger the age groups, the greater the increase in BMI

3.3 | Changes in lifestyle behaviours from 2019 to 2020

3.3.1 | Screen behaviours

Table 5 shows the changes in lifestyle behaviours of adolescents in Shanghai, China, from 2019–2020. The proportion of the 6047 junior high school students who watched TV for ≥2 h/day during the past week dropped from 16.6% in 2019 to 13.3% in 2020 ($p < 0.01$). The proportion of students who played computers for ≥2 h/day during the past week increased from 8.7% in 2019 to 9.6% in 2020 ($p = 0.05$). The proportion of students who used mobile electronic devices for ≥2 h/day during the past week increased from 22.2% in 2019 to 28.0% in 2020 ($p < 0.01$). The 25th to 75th percentile of mobile screen time increased from 0.25 to 1.50 h/day to 0.33–2.00 h/day ($p < 0.01$). From 2019 to 2020, the changes in the screen behaviours of boys and girls were consistent with the overall trend, except that the proportion of playing computers for ≥2 h/day increased significantly in girls, while no significant increase in boys. In 2019 and 2020, the proportion of boys who watched TV and played computers for ≥2 h/day was higher than that of girls, except for mobile screen time.

3.3.2 | Physical activities behaviours

The proportion of students who participated in moderate-to-vigorous physical activity (MVPA) for ≥60 min/day on all 7 days during the past week dropped from 14.4% in 2019 to 11.7% in 2020 ($p < 0.01$), and both boys and girls decreased, with boys being higher than girls. The number of days in which students participated in MVPA for ≥60 min/day during the past week dropped from 3.5 days in 2019 to 3.3 days in 2020 ($p < 0.01$). The proportion of students who spent ≥2 h/day on outdoor activities during the past week dropped from 36.8% in

TABLE 5 Lifestyle behaviours of adolescents in Shanghai, China, 2019–2020

	Total			Boys			Girls		
Variable	**2019**	**2020**	***p****	**2019**	**2020**	***p****	**2019**	**2020**	***p****
Screen behaviours									
TV time ≥2 h/day	1001 (16.6)	801 (13.3)	<0.01	600 (19.4)	453 (14.7)	<0.01	401 (13.6)	348 (11.8)	0.03
Computer time ≥2 h/day	524 (8.7)	581 (9.6)	0.05	323 (10.5)	329 (10.7)	0.79	201 (6.8)	252 (8.5)	<0.01
Mobile screen time ≥2 h/day	1292 (22.2)	1625 (27.9)	<0.01	633 (21.2)	837 (28.0)	<0.01	659 (23.3)	788 (27.9)	<0.01
Mobile screen time, hours per day (P_{25}–P_{75})	1.00 (0.25–1.50)	1.00 (0.33–2.00)	<0.01	0.75 (0.17–1.50)	1.00 (0.25–2.00)	<0.01	1.00 (0.33–1.50)	1.00 (0.50–2.00)	<0.01
Physical activity behaviours									
MVPA ≥ 60 min/day on all 7 days	870 (14.4)	706 (11.7)	<0.01	575 (18.6)	488 (15.8)	<0.01	295 (10.0)	218 (7.4)	<0.01
Days of MVPA ≥ 60 min/day (SD)	3.5 (2.2)	3.3 (2.1)	<0.01	3.8 (2.2)	3.5 (2.2)	<0.01	3.2 (2.1)	3.1 (2.0)	<0.01
Outdoor activities ≥2 h/day	1990 (36.8)	1457 (26.9)	<0.01	1065 (38.4)	794 (28.6)	<0.01	925 (35.1)	663 (25.1)	<0.01
Sleep duration									
Sleep duration, h/day (SD)	8.2 (1.1)	7.7 (1.1)	<0.01	8.3 (1.1)	7.8 (1.1)	<0.01	8.2 (1.1)	7.6 (1.1)	<0.01
Dietary behaviours									
Sugar-sweetened beverage ≥ 1 time/day	643 (10.6)	555 (9.2)	<0.01	374 (12.1)	320 (10.4)	0.01	269 (9.1)	235 (8.0)	0.07
Fresh fruit ≤ 1 time/day	4258 (70.5)	4722 (78.1)	<0.01	2163 (70.0)	2425 (78.5)	<0.01	2095 (70.9)	2297 (77.8)	<0.01
Vegetables ≤ 1 time/day	2651 (43.9)	2991 (49.5)	<0.01	1398 (45.2)	1562 (50.6)	<0.01	1253 (42.4)	1429 (48.4)	<0.01
Did not eat breakfast on all 7 days	891 (14.7)	1106 (18.3)	<0.01	373 (12.1)	493 (16.0)	<0.01	518 (17.5)	613 (20.8)	<0.01

Note: Data are *n* (%), median (P_{25}–P_{75}) or mean (SD).

Abbreviation: MVPA, moderate-to-vigorous physical activity.

*p value for paired chi-square test or Wilcoxon signed-rank test between 2019 and 2020.

TABLE 6 Influencing factors of obesity prevalence of adolescents in Shanghai, China, 2019–2020

	Total			Boys			Girls		
Parameter	**OR**	**95% CI**	***p***	**OR**	**95% CI**	***p***	**OR**	**95% CI**	***p***
Gender (boys vs. girls)	3.66	3.14–4.27	<0.01	/	/	/	/	/	/
District (urban vs. rural)	1.06	0.93–1.22	0.38	1.21	1.03–1.43	0.02	0.73	0.55–0.95	0.02
TV time (≥2 h vs. <2 h)	1.09	0.96–1.23	0.17	0.98	0.86–1.13	0.81	1.42	1.12–1.80	<0.01
Computer time (≥2 h vs. <2 h)	1.13	0.98–1.29	0.08	1.20	1.02–1.40	0.02	1.00	0.76–1.32	1.00
Mobile screen time, h/day	1.03	1.00–1.06	0.06	1.01	0.98–1.04	0.48	1.08	1.02–1.14	<0.01
MVPA≥60 min/day on all 7 days (yes vs. no)	0.88	0.78–0.99	0.04	0.88	0.77–1.00	0.06	0.87	0.63–1.2	0.39

2019 to 26.9% in 2020 ($p < 0.01$), and both boys and girls decreased, with boys being higher than girls (see Table 5).

3.3.3 | Sleep duration

The daily sleep duration during the past week decreased from 8.2 ± 1.1 h in 2019 to 7.7 ± 1.1 h in 2020 ($p < 0.01$), among which boys fell from 8.3 ± 1.1 h in 2019 to 7.8 ± 1.1 h in 2020 ($p < 0.01$), and girls dropped from 8.2 ± 1.1 h in 2019 to 7.6 ± 1.2 h in 2020 ($p < 0.01$).

3.3.4 | Dietary behaviours

The proportion of the 6047 junior high school students who had drunk sugar-sweetened beverages ≥1 time/day during the past week dropped from 10.6% in 2019 to 9.2% in 2020 ($p < 0.01$), of which, boys dropped from 12.1% in 2019 to 10.4% in 2020 ($p < 0.01$), and girls dropped from 9.1% in 2019 to 8.0% in 2020 ($p = 0.07$). The proportion of students who had eaten fresh fruits (excluding canned fruits) ≤1 time/day during the past week increased from 70.5% in 2019 to 78.1% in 2020 ($p < 0.01$), and both boys and girls increased. The proportion of students who had eaten vegetables ≤1 time/day during the past week increased from 43.9% in 2019 to 49.5% in 2020 ($p < 0.01$), and both boys and girls increased. The percentage of students who had not eaten breakfast on all 7 days increased from 14.7% in 2019 to 18.3% in 2020 ($p < 0.01$), and both boys and girls increased (see Table 5).

3.4 | Influencing factors of the obesity prevalence of adolescents in 2019–2020

Table 6 shows the results of the generalized estimation equation analysis of the obesity prevalence in 2019–2020. Overall, compared with girls, boys had a higher likelihood of having obesity with an odds ratio (OR) value of 3.66 (95% confidence interval [95% CI]: 3.14–4.27; $p < 0.01$). Students who participated in MVPA for ≥60 min/day on all 7 days during the past week had a lower likelihood of having obesity (OR: 0.88; 95% CI: 0.78–0.99, $p = 0.04$). For boys, boys in the urban areas had a higher likelihood of having obesity than those in rural. The likelihood of having obesity for boys who played computer games for ≥2 h/day was 1.20 times higher than those who played computer games for <2 h/day (95% CI: 1.02–1.40; $p = 0.02$). For girls, girls in the rural areas had a higher likelihood of having obesity than those in urban. Girls who watched TV for ≥2 h/day had a higher likelihood of having obesity (OR: 1.42; 95% CI: 1.12–1.80; $p < 0.01$). As time spent on mobile screen increased, the likelihood of having obesity for girls increased correspondingly, with an OR value of 1.08 (95% CI: 1.02–1.14; $p < 0.01$).

4 | DISCUSSION

This study found that 1 year after the COVID-19 pandemic, the prevalence of obesity among Chinese adolescents increased by 1.2%, mainly due to the increase in obesity among boys. Other studies have shown similar results.[14,17–19] A Chinese study with more than 10 000 youths found that before and after the COVID-19 lockdown, the prevalence of obesity among youths increased from 10.5% to 12.9%.[17] A simulation study in the United States showed that with an increase in the number of months of school suspension, the prevalence of childhood obesity increased correspondingly. In addition, the impact of COVID-19 on childhood obesity was larger among boys.[20] The latest review that included 17 028 111 children, adolescents and young adults aged from 5 to 25 years confirmed that during the COVID-19 era, children, adolescents and young adults gained weight.[18] Thus, public health interventions are urgently required to deal with the impact of the COVID-19 pandemic on childhood obesity.[21]

This research demonstrated that the COVID-19 pandemic harmed the lifestyle behaviours of adolescents. The mobile screen time and proportion of students who used mobile electronic devices for ≥2 h/day increased, while days of MVPA≥60 min/day and proportion of students who participated in MVPA for ≥60 min/day on all 7 days and who spent ≥2 h/day on outdoor activities decreased. These results agreed with what has been observed in other countries such as America,[22] Spain,[23,24] Egypt[25] and Canada.[26] A Spanish study found that during the confinement, the total time of physical activity decreased (−91 ± 55 min/day; $p < 0.01$), while the screen time increased (1.9 ± 2.6 h/day; $p < 0.01$). The prevalence of children who used screens ≥2 h/day increased from 66.0% to 87.7% ($p < 0.01$).[23] A French study that included 6491 children suggested that a total of 42.0% of children and 58.7% of adolescents reported decreased PA

during the lockdown, and 62.0% of children and 68.9% of adolescents reported increased screen time.[15] In addition, the results of the generalized estimation equation analysis indicated that students who participated in MVPA for ≥60 min/day on all 7 days had a lower likelihood of having obesity. Boys with computer time ≥2 h/day and girls with mobile screen time ≥2 h/day or TV time ≥ 2 h/day had a higher likelihood of having obesity. Therefore, the increase in screen time and the decrease in physical activity during the COVID-19 pandemic should cause important concern.[27]

In addition, it was observed in this study that 1 year after the COVID-19 pandemic, adolescents with TV time ≥2 h/day decreased, which was consistent with the results of the Youth Risk Behavior Surveillance System in the United States over the years.[28] Some studies have revealed that during the COVID-19 pandemic, the sleep duration of children increased.[13,17,29] This study indicated that the sleep duration of adolescents decreased, which may be because the second survey in this study was conducted in September–November of 2020, 1 year after the outbreak of the COVID-19 pandemic, not during the COVID-19 lockdown. In Shanghai, China, the lockdown period for the COVID-19 pandemic was February 2020 to May 2020.

The results of this study also suggested that 1 year after the COVID-19 pandemic, the proportion of adolescents who had drunk sugar-sweetened beverages ≥1 time/day decreased, while the proportion of students who had eaten fresh fruits≤1 time/day and had eaten vegetables ≤1 time/day increased. Some studies have also found similar results,[19,24,30] whereas other studies have found different results.[13,18] This may be because the second survey in this study was conducted in September–November of 2020, 1 year after the outbreak of the COVID-19 pandemic, not during the COVID-19 lockdown. And some studies mainly analysed the changes in dietary behaviour during the COVID-19 lockdown.[13,30]

This study has some limitations. First, most variables of lifestyle behaviours are categorical variables, not continuous variables. The primary reason was that this was a large-scale survey, and the subjects were students, and many variables were collected. Therefore, it was difficult to accurately estimate the specific time and food intake. Second, the data for this study came from the Surveillance of Students' Common Diseases and Health Influencing Factors in Shanghai, China, 2019–2020. It was not collected according to a cohort study, so the representativeness of the samples should be treated with caution. Third, except for the impact of the COVID-19 pandemic, the changes in obesity and lifestyle behaviours among adolescents from 2019 to 2020 may also have been affected by other factors, such as changes over time. However, the impact of the COVID-19 pandemic is undeniable.

Despite these limitations, using two-year data from 2019 to 2020 and longitudinal analysis method, this study compared and analysed the changes in obesity and related lifestyle behaviours of Chinese adolescents before the outbreak of the COVID-19 pandemic and 1 year after the outbreak of the COVID-19 pandemic. It can provide evidence for the global response to the impact of the COVID-19 pandemic on adolescent obesity. In addition, this study was a large-scale survey among adolescents, and the heights and weights were measured by professionals. This makes the data more accurate and credible. And many obesity-related lifestyle behaviours were analysed in this study, including screen behaviours, physical activity behaviours, sleep duration, and dietary behaviours.

5 | CONCLUSION

Using two-year data from 2019 to 2020 and longitudinal analysis method, this study found that 1 year after the outbreak of the COVID-19 pandemic, the BMI and obesity prevalence of Chinese adolescents increased, mainly because of the increase in boys. Obesity-related lifestyle behaviours have also changed. The main changes include the proportion of students participating in outdoor activities and physical activities has decreased, and the time spent on mobile screens has increased. This study provides important evidence to shape strategies to reverse the impact of the COVID-19 pandemic on adolescent obesity.

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CONFLICT OF INTEREST

The authors have no conflicts of interest relevant to this article to disclose.

AUTHOR CONTRIBUTIONS

Dongling Yang analysed the data, generated figures, and took full responsibility for the integrity of the data. **Dongling Yang** and **Chunyan Luo** drafted the manuscript. **Dongling Yang**, **Wenjuan Qi**, **Shuangxiao Qu**, **Yuefang Zhou**, and **Lijing Sun** conducted research. **Chunyan Luo**, **Xiaogang Feng** and **Huanyu Wu** designed the study, coordinated and supervised data collection. All authors participated in the interpretation of the results, critically revised the manuscript for important intellectual content and approved the final manuscript as submitted, and agreed to be accountable for all aspects of the work.

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