

A longitudinal study on differential impacts of the COVID-19 pandemic and normalized prevention and control on overweight and obese adolescents in China

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Abstract

Objective

To investigate the impact of the coronavirus disease 2019 (COVID-19) pandemic and its normalized prevention and control phase on the body mass index (BMI) and prevalence of overweight and obesity among adolescents aged 13–18 years in China, providing a basis for formulating growth and development intervention strategies for them in the post-pandemic era.

Methods

Using a random cluster sampling method, 120,459 adolescents aged 13–18 years from 15 junior and senior high schools across 4 districts/prefectures in Xinjiang, China, were selected as study subjects based on geographical distribution characteristics from 2017 to 2021. Height and weight were measured in strict accordance with the National Student Physical Health Standard, and physical status was classified into underweight, normal weight, overweight, obesity, and combined "overweight+obesity" based on BMI. Relevant data were analyzed using normality tests, one-way ANOVA, χ^2 test, and binary logistic regression. The significance level was set as 5%.

Results

The mean BMI of adolescents aged 13–18 years in 2020 increased significantly by 0.2 kg/m^2 compared with previous years, while showing a declining trend in 2021 ($F = 104.862, P < 0.001$). BMI changes exhibited gender and age differences, with girls showing greater fluctuation than boys ($F = 114.950, 30.063$, both $P < 0.001$). Statistically significant differences were also observed across all age groups (all $P < 0.05$). Detection rates of nutritional status categories showed: compared with 2017–2019, the underweight rate decreased to 10.6% in 2020, while overweight and "overweight+obesity" rates increased to 9.5% and 12.0%, respectively (both $P < 0.05$); compared with 2020, the underweight rate rebounded to 13.9% in 2021, while overweight and "overweight+obesity" rates decreased to 8.0% and 10.7%, respectively (both $P < 0.05$), with particularly significant changes observed in girls and the 13–15-year-old group. Logistic regression analysis (with 2017 as reference) indicated that in 2020, the risk of underweight decreased (OR = 0.668, 95% CI: 0.633–0.706), while the risks of overweight (OR = 1.128, 95% CI: 1.199–1.366) and "overweight+obesity" (OR = 1.364, 95% CI: 1.286–1.448) increased; in 2021, the risk of underweight increased (OR = 0.917, 95% CI: 0.872–0.965), while the risk of "overweight+obesity" decreased (OR = 1.201, 95% CI: 1.131–1.275), with these associations being more pronounced in girls.

Conclusion

The initial stage of the COVID-19 pandemic exerted a significant negative impact on the weight status of Chinese adolescents aged 13–18 years, manifested by increased BMI and elevated detection rates of overweight and obesity. As prevention and control entered a normalized phase, this impact gradually diminished, with weight distribution showing a tendency to return to pre-pandemic status. Future efforts should focus on strengthening long-term dynamic monitoring of adolescent weight changes and developing and implementing precise health interventions to prevent undesirable physical status and promote the overall healthy development of adolescents.

1 Introduction

Overweight and obesity in adolescents have become a public health issue of global concern. According to statistics from the World Health Organization (WHO), between 1975 and 2016, the prevalence of overweight and obesity among people aged 5 to 19 globally increased significantly from 4% to 18%¹. With the rapid development of socio-economic conditions and profound changes in residents' lifestyles, the nutritional and health status of adolescents in China has undergone a rapid epidemiological transition from malnutrition to overweight and obesity². As of 2019, about 20% of adolescents in China are overweight or obese³. If this trend continues, it will pose a severe challenge to the country's long-term public health system. Studies have shown that obesity during school age is not only closely related to physical diseases such as ischemic heart disease⁴, type 2 diabetes, and asthma, but may also lead to psychosocial issues such as anxiety and depression^{5,6}. More importantly, obesity in adolescence has a significant "track

effect", with about 70% of obese adolescents continuing this condition into adulthood, significantly increasing their risk of developing chronic non-communicable diseases^{7,8}. Therefore, public health institutions in various countries have successively launched a series of policies and projects aimed at curbing the epidemic trend of obesity in school and community environments^{9,10}.

Since December 2019, COVID-19 has spread rapidly around the world. To effectively control the spread of the epidemic, many governments, including China, have successively implemented strict non-pharmaceutical intervention measures such as regional lockdowns, home quarantine, and school closures. In the spring of 2020, Xinjiang extended the winter vacation for primary and secondary schools to the end of February, and gradually resumed offline teaching from March 23rd. The start time of the autumn semester in the same year was also postponed¹¹. After entering the normalization phase of epidemic prevention and control, China continues to face the dual pressure of "preventing importation from outside and preventing rebound from within"¹². Against this backdrop, daily physical activities and extracurricular exercise opportunities in schools have generally decreased, and students' lifestyles have undergone significant changes, mainly manifested as decreased physical activity levels, prolonged screen time, imbalanced dietary structure, and impaired sleep quality^{13–16}. These behavioral changes provide a potentially risky environment for the occurrence and development of overweight and obesity in adolescents. Existing research mostly focuses on the short-term changes in the obesity rate among adolescents during the early outbreak of the epidemic (from the end of 2019 to the end of 2020). Multiple surveys have indicated that during this period, the detection rate of overweight and obesity among students showed an upward trend, while physical activity levels significantly decreased^{17–20}.

However, existing research on the dynamic changing trends and sustained effects of adolescents' weight status during the normalized phase of epidemic prevention and control (2021 and beyond), as well as the long-term impact of normalized prevention and control measures on adolescents' growth and development, is still insufficient, making it difficult to effectively guide the formulation of health management strategies for adolescents in the post-pandemic era. Based on the above background, this study utilizes continuous health monitoring data from adolescents aged 13 to 18 during 2017 to 2021 in China, aiming to systematically analyze the differences in the impact of different stages of the COVID-19 pandemic (early stage of the epidemic and normalized period of prevention and control) on the body mass index (BMI) and prevalence of overweight and obesity among this group. The research results not only help reveal the phased effects of public health emergencies on adolescents' weight status but also provide empirical evidence for the government and education departments to formulate precise and effective health promotion strategies for adolescents in the post-pandemic era.

2 Methods

2.1 Participants

The study employed a random cluster sampling method. Between 2017 and 2021, based on the geographical distribution characteristics of the Xinjiang region, 15 middle schools with students aged 13 to 18 from 4 districts/prefectures were selected as the research subjects. The sampling process fully considered the representativeness of the geographical distribution. The inclusion and exclusion of samples strictly followed the "National Student Physical Health Standards": individuals with severe diseases, physical disabilities, developmental abnormalities, or other conditions that prevented them from completing the prescribed physical fitness tests were excluded. To ensure longitudinal comparability of data over five years, only schools that continuously had junior high school or high school departments during the study period were retained. Due to the small number of students aged ≤ 12 and ≥ 19 (less than one-third of the minimum sample size for the main age group), the final age range of the research subjects was determined to be 13 to 18 years old (inclusive). After preliminary screening, 59 extreme value samples with BMI ≤ 11 kg/m² or ≥ 50 kg/m² were further excluded. The samples were divided into six age groups, with 1-year intervals, and within each age group, stratification was performed by gender, ultimately forming 12 strata. The total number of valid samples was 120,459, including 51,697 males and 68,762 females. There were differences in sample size between gender and age groups. The present study strictly adhered to the principles of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards, and had been also in accordance with relevant ethics standards of the Ethics Review Committee from South China University of Technology (grant number: SCUT-SPT-2022-003). And before formally participating in this survey, all participants provided their written informed consent, prior to the formal data collection (A minor aged 16 has obtained written consent from both their parents or legal guardians).

2.2 Measurement

Measurements of height and weight are conducted annually from September 1st to October 31st. Physical fitness test indicators are tested according to the requirements and methods outlined in the "National Student Physical Health Standards (Revised in 2014)" issued by the Ministry of Education ²¹. The standardized and unified technical standards are used to measure the height and weight of adolescents, with height measured to an accuracy of 0.1 cm and weight measured to an accuracy of 0.1 kg. The BMI is calculated as follows: $BMI = \text{weight (kg)} / \text{height}^2 (m^2)$.

The classification of physical status is based on different national standards applicable to different age groups. For students aged 13 to 17: overweight and obesity are determined based on the gender- and age-specific BMI thresholds in the "Screening for Overweight and Obesity in School-Age Children and Adolescents" (WS/T 586—2018) ²²; underweight (combined moderate and severe and mild wasting) is determined based on the "Screening Criteria for Malnutrition in School-Age Children and Adolescents" (WS/T 456—2014) ²³. For students aged 18 and above: the adult standards recommended by the Working Group on Obesity in China (WGOC) are used ²⁴ to classify: underweight ($BMI < 18.5 \text{ kg/m}^2$), overweight ($24.0 \text{ kg/m}^2 \leq BMI < 28.0 \text{ kg/m}^2$), and obesity ($BMI \geq 28.0 \text{ kg/m}^2$), regardless of gender. Ultimately, all subjects are classified into five nutritional status categories: underweight, normal weight, overweight, obesity, and "overweight + obesity" (the latter two categories combined).

2.3 Statistical methods

Data were organized using Excel 2016. Measurement data were described as mean $\pm$ standard deviation ($M \pm SD$), and enumeration data were described as frequency (percentage). The Kolmogorov-Smirnov test was used for normality testing. One-way analysis of variance (ANOVA) was used to compare the differences in BMI (overall, male, and female) across the years from 2017 to 2021. If the difference was statistically significant, the Scheffe method was used for post hoc pairwise comparisons. Chi-square test (χ^2 test) was used to analyze the differences in the composition of the five nutritional statuses between different years and genders, with special attention paid to comparing the detection rates in 2020 with those in 2021 and the closest years before 2020. Binary logistic regression analysis was used to examine the trend of the impact of year on nutritional status. Models were constructed with low weight, overweight, obesity, and "overweight+obesity" as dependent variables and year as the independent variable. Gender-specific models adjusted for age (continuous variable); the overall model adjusted for both age and gender. To test the trend, the years from 2017 to 2021 were coded as 0–4 as continuous variables, with 2017 as the reference, to calculate the odds ratio (OR) and 95% confidence interval (CI). All analyzes were performed using SPSS 27.0 software, with a significance level of $\alpha = 0.05$. Graphs were drawn using GraphPad Prism 9.3.1 software.

3 Results

3.1 Basic characteristics of participants

This study included a total of 120,459 adolescents aged 13 to 18 from Xinjiang, China, including 51,697 males (42.9%) and 68,762 females (57.1%). The sample sizes for each year from 2017 to 2021 were 23,641, 24,482, 23,706, 23,731, and 24,899, respectively. The proportions of males in each year were 43.1%, 43.0%, 44.3%, 42.3%, and 43.3%, respectively. There was no statistically significant difference in gender composition between different years ($\chi^2 = 9.341$, $P = 0.053$). See Table 1 for details.

3.2 Difference analysis of adolescents' BMI from 2017 to 2021

Between 2017 and 2021, the overall BMI of adolescents showed a slow upward trend, with an average annual increase of approximately 0.1 kg/m^2 for both genders. Notably, the BMI increase was significant in 2020, reaching 0.2 kg/m^2 , which was higher than that of previous years. By 2021, a downward trend emerged, and the overall difference was statistically significant ($F = 104.862$, $P < 0.001$). Gender analysis revealed that the BMI increase was more pronounced in girls in 2020 (0.4 kg/m^2 , $F = 114.950$, $P < 0.001$), while a significant decrease was only observed in boys in 2021 ($F = 30.063$, $P < 0.001$). The BMI fluctuation patterns varied across age groups, and the differences were statistically significant (all $P < 0.05$). Specifically, compared to 2019, significant increases in BMI were observed in boys aged 13–14 years, all age groups except for girls aged 18–19 years, and the combined age group of boys and girls under 16 years old in 2020. Conversely, compared to 2020, significant decreases in BMI were observed in boys aged 13–14 years and the overall population, all age groups except for girls aged 18–19 years, and the combined age group of boys and girls under 17 years old in 2021 (all comparisons, $P < 0.05$). Details are provided in Table 1.

Table 1
BMI of adolescents aged 13–18 in China from 2017 to 2021

Gender	Age	2017		2018		2019		2020		2021		F value	P value
		N	M $\pm$ SD	N	M $\pm$ SD	N	M $\pm$ SD	N	M $\pm$ SD	N	M $\pm$ SD		
Boys	13岁<14	859	18.8 $\pm$ 2.8*	1139	19.2 $\pm$ 2.8	1265	18.8 $\pm$ 3.3*	1510	19.7 $\pm$ 3.0	1535	18.9 $\pm$ 2.8*	29.990	<0.001
	14岁<15	1194	19.1 $\pm$ 3.0*	1359	19.5 $\pm$ 2.6	1507	19.3 $\pm$ 3.2	1519	19.6 $\pm$ 2.8	1830	19.3 $\pm$ 2.9	26.433	<0.001
	15岁<16	1485	19.5 $\pm$ 2.9	1602	19.9 $\pm$ 2.7	1677	19.9 $\pm$ 3.1	1723	19.9 $\pm$ 3.1	1884	19.7 $\pm$ 3.0	15.583	<0.001
	16岁<17	2081	20.0 $\pm$ 2.8	2007	20.3 $\pm$ 2.9	2035	20.2 $\pm$ 3.0	1922	20.2 $\pm$ 3.0	2171	20.0 $\pm$ 3.3	3.400	<0.01
	17岁<18	2700	20.4 $\pm$ 2.8	2330	20.4 $\pm$ 2.8	2018	20.5 $\pm$ 3.1	1946	20.3 $\pm$ 2.8	1921	20.6 $\pm$ 3.5	2.430	<0.05
	18岁<19	1868	20.6 $\pm$ 2.9	2087	20.8 $\pm$ 2.8*	1648	20.6 $\pm$ 2.9	1429	20.5 $\pm$ 3.0	1446	20.7 $\pm$ 3.1	3.913	<0.01
	13岁<19	10187	20.0 $\pm$ 2.9	10524	20.2 $\pm$ 2.8	10150	20.0 $\pm$ 3.2	10049	20.0 $\pm$ 3.0	10787	19.9 $\pm$ 3.2*	30.063	<0.001
Girls	13岁<14	881	19.0 $\pm$ 3.0*	1041	19.1 $\pm$ 2.6*	1294	19.0 $\pm$ 3.2*	1443	19.6 $\pm$ 2.7	1562	19.1 $\pm$ 2.6*	27.377	<0.001
	14岁<15	1157	19.4 $\pm$ 2.9*	1310	19.6 $\pm$ 2.6*	1397	19.4 $\pm$ 3.0*	1532	20.1 $\pm$ 2.8	1742	19.6 $\pm$ 2.8*	34.554	<0.001
	15岁<16	2029	19.7 $\pm$ 2.7*	2138	19.8 $\pm$ 2.6*	2171	20.0 $\pm$ 2.9*	2143	20.5 $\pm$ 2.9	2251	20.0 $\pm$ 3.0*	19.308	<0.001
	16岁<17	3161	19.9 $\pm$ 2.6*	3196	20.0 $\pm$ 2.6*	3168	20.3 $\pm$ 2.9*	3030	20.6 $\pm$ 2.6	3077	20.3 $\pm$ 2.8*	24.582	<0.001
	17岁<18	3755	20.1 $\pm$ 2.7*	3515	20.1 $\pm$ 2.6*	3234	20.5 $\pm$ 2.9*	3292	20.7 $\pm$ 2.6	3238	20.5 $\pm$ 2.8*	39.582	<0.001
	18岁<19	2471	20.4 $\pm$ 2.7	2758	20.1 $\pm$ 2.6*	2292	20.6 $\pm$ 2.8	2242	20.6 $\pm$ 2.7	2242	20.6 $\pm$ 2.8	26.661	<0.001
	13岁<19	13454	19.9 $\pm$ 2.7*	13958	19.9 $\pm$ 2.6*	13556	20.1 $\pm$ 3.0*	13682	20.5 $\pm$ 2.7	14112	20.1 $\pm$ 2.9*	114.950	<0.001
Total	13岁<14	1740	18.9 $\pm$ 2.9*	2180	19.2 $\pm$ 2.7*	2559	18.9 $\pm$ 3.3*	2953	19.6 $\pm$ 2.8	3097	19.0 $\pm$ 2.7*	55.554	<0.001
	14岁<15	2351	19.2 $\pm$ 2.9*	2669	19.6 $\pm$ 2.6*	2904	19.3 $\pm$ 3.1*	3051	19.9 $\pm$ 2.8	3572	19.5 $\pm$ 2.8*	59.997	<0.001
	15岁<16	3514	19.6 $\pm$ 2.8*	3740	19.9 $\pm$ 2.6*	3848	19.9 $\pm$ 3.0*	3866	20.2 $\pm$ 3.0	4135	19.8 $\pm$ 3.0*	26.600	<0.001

Note: The F-value and P-value in the table are the results of one-way ANOVA. * represents pairwise comparisons between 2020 and other years, with $P < 0.05$.

Gender	Age	2017		2018		2019		2020		2021		F value	P value
		N	M $\pm$ SD	N	M $\pm$ SD	N	M $\pm$ SD	N	M $\pm$ SD	N	M $\pm$ SD		
	16~<17	5242	19.9 $\pm$ 2.7*	5203	20.1 $\pm$ 2.7*	5203	20.3 $\pm$ 2.9	4952	20.4 $\pm$ 2.8	5248	20.2 $\pm$ 3.0*	17.029	<0.001
	17~<18	6455	20.2 $\pm$ 2.8*	5845	20.2 $\pm$ 2.7*	5252	20.5 $\pm$ 3.0	5238	20.6 $\pm$ 2.7	5159	20.5 $\pm$ 3.1	21.581	<0.001
	18~<19	4339	20.5 $\pm$ 2.8	4845	20.4 $\pm$ 2.7	3940	20.6 $\pm$ 2.9	3671	20.6 $\pm$ 2.8	3688	20.6 $\pm$ 2.9	17.208	<0.001
	13~<19	23641	19.9 $\pm$ 2.8*	24482	20.0 $\pm$ 2.7*	23706	20.1 $\pm$ 3.1*	23731	20.3 $\pm$ 2.8	24899	20.0 $\pm$ 3.0*	104.862	<0.001
Note: The F-value and P-value in the table are the results of one-way ANOVA. * represents pairwise comparisons between 2020 and other years, with $P < 0.05$.													

3.3 Dynamic analysis of adolescent physical status from 2017 to 2021

Between 2017 and 2021, the nutritional status of adolescents in Xinjiang exhibited significant fluctuations. In 2020, the prevalence rates of underweight, normal weight, overweight, obesity, and combined overweight and obesity among adolescents were 10.6%, 77.4%, 9.5%, 2.5%, and 12.0%, respectively; in 2021, these rates were 13.9%, 75.4%, 8.0%, 2.8%, and 10.7%, respectively. Statistical analysis revealed that the differences in the detection rates of different nutritional statuses among adolescents in each year from 2017 to 2021 were statistically significant (all $P < 0.01$), with significant gender differences (all $P < 0.001$). Compared with the previous baseline, during the COVID-19 pandemic lockdown management in 2020, the prevalence rates of underweight and overall underweight among girls significantly decreased, while the prevalence rate of overweight significantly increased. The detection rates of overweight combined with obesity among boys, girls, and the overall population all significantly increased (all $P < 0.05$); however, there were no statistically significant differences in the detection rates of underweight among boys and the prevalence rates of obesity among various populations (all $P > 0.05$). Compared with 2020, in 2021, the detection rates of underweight among boys and girls both significantly rebounded, while the prevalence rate of overweight significantly decreased, and the prevalence rates of overweight combined with obesity among girls and the overall population also significantly decreased (all $P < 0.05$); there were no significant changes in the prevalence rate of overweight combined with obesity among boys and the prevalence rates of obesity among various populations (all $P > 0.05$). The above results indicate that the COVID-19 pandemic lockdown management in 2020 led to an increase in body weight among adolescents aged 13 to < 19 years, and the body weight levels returned to normal after the normalization of prevention and control measures in 2021. This trend was particularly evident among girls and adolescents aged 13 to < 16 years (see Table 2 and Fig. 1).

Table 2
Physical status of adolescents aged 13–18 in China from 2017 to 2021

Gender	Year	Statistical value	Low body weight	Normal weight	Overweight	Obesity	Overweight + Obesity	χ^2 value	P value
Boys	2017		1882(18.5)	7245(71.1)	892(8.8)	172(1.7)	1064(10.4)	164.046	<0.001
	2018		1411(13.4)	7995(76.0)	915(8.7)	185(1.8)	1100(10.5)	90.638	<0.001
	2019		1609(15.9)	7447(73.4)	765(7.5)	329(3.2)	1094(10.8)*	106.644	<0.001
	2020		1376(13.7)	7463(74.3)	912(9.1)	298(3.0)	1210(12.0)	192.884	<0.001
	2021		1855(17.2) [#]	7670(71.1)	893(8.3) [#]	369(3.4)	1262(11.7)	228.102	<0.001
		χ^2 value	149.774	93.584	18.428	112.598	22.930		
		P value	<0.001	<0.001	<0.01	<0.001	<0.001		
Girls	2017		1838(13.7)	10540(78.3)	895(6.7)	181(1.3)	1076(8.0)	164.046	<0.001
	2018		1739(12.5)	11208(80.3)	830(5.9)	181(1.3)	1011(7.2)	90.638	<0.001
	2019		1646(12.1)*	10527(77.7)	1104(8.1)*	279(2.1)	1383(10.2)*	106.644	<0.001
	2020		1143(8.4)	10902(79.7)	1333(9.7)	304(2.2)	1637(12.0)	192.884	<0.001
	2021		1600(11.3) [#]	11100(78.7)	1089(7.7) [#]	323(2.3)	1412(10.0) [#]	228.102	<0.001
		χ^2 value	211.427	37.036	166.135	71.235	227.035		
		P value	<0.001	<0.001	<0.001	<0.001	<0.001		
Total	2017		3716(15.7)	17785(75.2)	1787(7.6)	353(1.5)	2140(9.1)		
	2018		3150(12.9)*	19203(78.4)	1745(7.1)	366(1.5)	2111(8.6)		
	2019		3255(13.7)	17974(75.8)	1869(7.9)*	608(2.6)	2477(10.4)*		
	2020		2519(10.6)	18365(77.4)	2245(9.5)	602(2.5)	2847(12.0)		
	2021		3455(13.9) [#]	18770(75.4)	1982(8.0) [#]	692(2.8)	2674(10.7) [#]		
		χ^2 value	281.775	105.795	100.871	179.042	194.082		
		P value	<0.001	<0.001	<0.001	<0.001	<0.001		
Note: The percentages are indicated within parentheses. The χ^2 test on the right side is for comparison between males and females. The χ^2 test between gender groups is indicated below each year. * denotes comparison between 2020 and the year with the closest detection rate before 2020, while # denotes comparison between 2020 and 2021. $P < 0.05$.									

3.4 Logistic regression analysis of adolescent physical status from 2017 to 2021

This study employed a binary logistic regression model. Year was treated as a continuous variable to analyze temporal trends in nutritional status indicators from 2017 to 2021, after adjusting for gender and age. Target nutritional status was coded as 1, and non-target status as 0 (e.g., underweight = 1, non-underweight = 0, and so on). The results showed that, compared to 2017, the underweight rate among girls and overall decreased significantly from 2018 to 2021. The combined incidence of overweight, obesity, and overweight-obesity increased significantly ($P < 0.001$). Further regression analysis used year as a categorical variable. It revealed a significant decrease in the underweight rate in 2020 (OR = 0.668, 95% CI: 0.633–0.706). It also showed a significant increase in the overweight rate (OR = 1.128, 95% CI: 1.199–1.366) and the combined rate of overweight and obesity (OR = 1.364, 95% CI: 1.286–1.448). The magnitude of change was greater in girls than in boys, but there was no statistically significant difference in the obesity rate across the years ($P > 0.05$). Following the normalization of the prevention and control phase in 2021, the underweight rate rebounded significantly (OR = 0.917, 95% CI: 0.872–0.965). The combined rate of overweight and obesity decreased significantly (OR

= 1.201, 95% CI: 1.131–1.275). Changes in underweight, overweight, and combined overweight-obesity were more pronounced in girls. In boys, the magnitude of change was smaller or not statistically significant. The trends and categorical analysis results are shown in Fig. 2.

3 Discussion

This study reveals the differentiated impacts of different stages of the COVID-19 pandemic on the body weight and nutritional status of adolescents aged 13 to 18 in Xinjiang. The results show that in the first year of the COVID-19 outbreak, the BMI of adolescents aged 13 to 18 in Xinjiang increased, and the detection rates of overweight and obesity showed an upward trend. Among them, the increase in the overweight rate was particularly evident, while the low weight rate decreased accordingly. In the following year, after entering the normalization of prevention and control measures, the mean BMI of adolescents declined slightly, the rates of overweight and obesity decreased, and the low weight rate rebounded, with more significant changes observed in girls and younger age groups. This result indicates that the negative impact of the pandemic on the body weight of adolescents aged 13 to 18 in Xinjiang has stage characteristics. Although the effect weakened after adjustments to prevention and control measures, long-term monitoring is still needed to assess the long-term impact. The findings of this study are consistent with observations from multiple countries worldwide.

A longitudinal study in the United States tracked 264 children and adolescents aged 8 to 14 and found that BMI increased from 18.8 kg/m² to 20.8 kg/m² during the pandemic ²⁵. A survey of 178 children aged 8 to 10 in the United Kingdom showed that the average BMI increased by 1.5 kg/m² and body weight increased by 6.3 kg during the lockdown period ²⁶. Children and adolescents aged 10 to 18 in Italy ²⁷ and 2 to 18 in Greece ²⁸ also showed a trend of weight increase. Domestic research also shows that the BMI of adolescents aged 11 to 16 increased from 20.3 kg/m² to 21.2 kg/m² one year after the pandemic ¹⁴; another national retrospective survey involving 10,082 adolescents found that BMI increased from 21.8 kg/m² to 22.6 kg/m² within one month of the lockdown ¹⁸. Although this study did not directly measure the short-term effects of the lockdown, the annual observation still showed that the BMI increase in adolescents aged 13 to 18 in Xinjiang expanded from 0.1 kg/m² in previous years to 0.2 kg/m², representing a 200% increase. This suggests that if a short-term assessment is conducted, the actual increase may be even more significant. The results of this study are consistent with the aforementioned research. In the first year of the pandemic, the BMI increased among adolescents aged 13 to 18 in Xinjiang by 0.2 kg/m². Although the absolute value is not high, it represents a 200% increase compared to the annual average increase before the pandemic (0.1 kg/m²). It is worth noting that this study was analyzed on an annual basis and failed to capture the more drastic BMI fluctuations that may have occurred during the early stages of the pandemic lockdown.

The increase in BMI directly leads to changes in nutritional status distribution. Logistic regression analysis showed that the low weight rate among adolescents aged 13 to 18 in Xinjiang significantly decreased in 2020 (OR = 0.668, 95% CI: 0.633–0.706), while the rate of overweight and obesity significantly increased (OR = 1.364, 95% CI: 1.286–1.448). The change in the rate of simple obesity was not significant. In 2021, the low weight rate among girls rebounded (OR = 0.865, 95% CI: 0.805–0.930), while the rate of overweight and obesity showed a downward trend (OR = 1.277, 95% CI: 1.175–1.388). The rate of overweight and obesity among adolescents aged 13 to 18 in Xinjiang increased from 10.4% in 2019 to 12.0% in 2020, consistent with multiple domestic and international research trends. It is worth noting that one year after the pandemic, the obesity rate among domestic adolescents increased from 14.2% to 15.4% ¹⁴, and the rate of overweight and obesity among college students increased from 21.3% to 25.1% in a short period of time ¹⁸. The rate of overweight and obesity among children aged 7 to 10 in Australia increased from 20.7% to 26.2% between September 2019 and March 2021 ²⁰, suggesting that the impact of the pandemic on the weight of adolescents in Western countries may be more severe. This study also found that in 2021, the low weight rate among adolescents aged 13 to 18 in Xinjiang rebounded, while the obesity rate remained unchanged, similar to the research results of the Czech Republic, where the low weight rate among students in grades 6 to 9 increased from 19.2% to 25.4% and the obesity rate increased from 2.1% to 3.7% after the end of lockdown ¹⁹. This indicates that weight changes formed during the lockdown period tend to regress after the normalization of prevention and control measures, but the lifestyle habits developed during the pandemic continue to have a negative impact on weight. Some studies have indicated that 21.4% of overweight individuals before the pandemic turned into obese individuals during subsequent observations ²⁹. This study speculates that there may be a transition from low weight and normal weight to overweight status among adolescents in Xinjiang, which is related to the relatively low baseline BMI levels and the small sample size of obesity rates.

Changes in BMI among adolescents are driven by multiple factors. Before and after the pandemic lockdown, there was a significant decrease in the frequency of active transportation and moderate-intensity household chores among adolescents, accompanied by a notable increase in sedentary time¹⁸. In China, the proportion of primary and secondary school students using mobile electronic devices for ≥ 2 hours per day increased, while the number of individuals engaging in moderate-to-vigorous physical activity (MVPA) for ≥ 60 minutes per day decreased¹⁴. Bingham et al.³⁰ also reached similar conclusions. Surveys indicate that the proportion of adolescents who do not participate in any physical activity other than physical education classes has increased from 69.4% to 74.3%, and the proportion of those who use mobile phones and social networks for more than 14 hours per week has risen from 9.4% to 14.8%¹⁹. In addition to behavioral changes, the impact of the pandemic on adolescents' mental health cannot be overlooked. Social messages about body image received by individuals³¹ and their subjective body satisfaction³² are both factors related to weight changes. An online survey conducted in the autumn of 2020 showed that among 452 adolescents aged 11 to 17, 53% reported having encountered at least one form of weight stigmatization through social media during the pandemic, leading to a significant increase in dissatisfaction with their own body image, especially among girls with higher BMI³³.

Even during the normalization of prevention and control measures, although measures such as wearing masks, social distancing, and travel management have been relaxed compared to the initial stage, the long-term negative impacts are difficult to eliminate in the short term^{12,34}, and adolescents are still at risk of overweight and obesity. In terms of gender differences, this study shows that although the overweight and obesity rate among boys in Xinjiang is higher than that among girls in each year, the impact of the pandemic on girls is more significant, with greater fluctuations in BMI and overweight and obesity rates among girls in 2020–2021. This result is inconsistent with some domestic and international research conclusion^{14,26,35}. Maltoni et al.²⁷ pointed out that among adolescents aged 10 to 18 in Italy, the average weight increase during the lockdown period was greater among boys than girls. Mazza et al.³⁶ reported similar gender differences among college students aged 18 and above, and found that compared to normal weight individuals, the weight increase was more pronounced among previously obese individuals. Pop et al.³⁷ noted that environmental factors have a more significant impact on boys' weight. Another study suggests that women are more prone to fat accumulation than men³⁸. Xinjiang is a multi-ethnic region. Compared to developed cities on the mainland, there may be differences in the daily habits and exercise patterns of adolescents.

In some families, male adolescents may have more opportunities and space for activities due to their personal interest in sports or taking on more household chores. In addition, during puberty, males experience rapid height growth, which may offset the increase in weight to some extent, resulting in less significant changes in BMI compared to females. In terms of age differences, this study found that changes in BMI and nutritional status were more significant in the younger age group. Consistent with the research of Brooks et al.³⁹, the study results indicated that the weight gain of children aged 8 to 12 was more pronounced than that of adolescents aged 15 to 17 during the pandemic. The authors believe that this may be because the screen usage habits of adolescents during puberty have become more entrenched, while younger children are forced to spend longer periods of time on screens to cope with lockdown life. This explains, to some extent, the age stratification results of this study. Furthermore, senior-year adolescents face the pressure of college entrance exams after the pandemic, leading to reduced physical activity time, and psychological and physiological fatigue may inhibit weight gain.

This study possesses the following advantages: it is the first to systematically evaluate the impact of different stages of the COVID-19 pandemic on adolescents' BMI and nutritional status in Xinjiang, China, supplementing epidemiological data with regional specificity; the sample size is large, and all physical data are derived from standardized field measurements, ensuring good representativeness; the study spans the initial strict lockdown phase of the outbreak and the subsequent normalized prevention and control phase, facilitating a preliminary exploration of the continuity of the pandemic's impact. However, this study still has several limitations: firstly, the sudden outbreak of the pandemic prevented a prospective design, potentially limiting sample representativeness; secondly, it did not control for confounding factors such as ethnicity, region, and socioeconomic status, nor did it deeply analyze potential mediating variables such as diet, sleep, and physical activity. Future research should conduct a multi-factor analysis to clarify the long-term impact of the pandemic on adolescent growth and development.

In addition, this study also has four limitations. At first, the causal inference is restricted: the unexpected outbreak precluded a prospective design, lacking exposure data such as individual quarantine duration and lockdown tiers, thus precluding definitive establishment of causality between prevention measures and weight changes—our conclusions represent associative evidence. Second, key confounders were uncontrolled: multilevel factors including ethnicity, urban-rural residence, and socioeconomic status

were not adjusted, potentially introducing residual confounding, obscuring subgroup-specific trends, and limiting generalizability. Third, mediating mechanisms remain unclear: core variables such as physical activity, diet, sleep, and psychological factors (e.g., weight stigma) were not measured, hindering explanation of "why girls and younger groups showed more pronounced changes" and preventing identification of precise intervention targets. Fourth, sample representativeness is insufficient: covering only Xinjiang students and excluding those from schools that closed mid-study or were lost to follow-up, selection bias may have led to underestimation of the pandemic's true impact on vulnerable populations. Despite these limitations, this study, based on large-scale longitudinal data, clearly depicted weight change trends among adolescents across different pandemic phases, providing important signals for public health surveillance. Future research should employ Ecological Momentary Assessment, multilevel modeling, and latent class analysis to elucidate underlying mechanisms and develop differentiated intervention strategies.

4 Conclusion

Within one year of the COVID-19 outbreak, the BMI and overweight/obesity rates among adolescents in Xinjiang significantly increased, while the underweight rate decreased. The following year, the overweight/obesity rate eased but remained higher than pre-pandemic levels, and the underweight rate rebounded, with more pronounced changes among girls and younger adolescents. The COVID-19 pandemic has had a negative impact on the growth and development of adolescents, with potential long-term effects. During the routine prevention and control phase of the pandemic, long-term lockdown in most regions have been lifted, allowing adolescents to attend classes offline normally. Therefore, it is important to ensure the frequency of physical education classes in schools and the intensity of exercise during classes. School sports clubs and extracurricular sports clubs can continue to operate under proper prevention and control measures. The family is a major factor influencing the development of unhealthy lifestyle habits among adolescents. Parents should enhance their own knowledge of health care, fully recognize the importance of obesity prevention and control in the post-pandemic era, and set an example by actively guiding adolescents to participate in family activities and household chores as a way of spending their leisure time, thereby reducing their sedentary time and use of electronic devices ⁴⁰. Additionally, adolescents, especially girls, are prone to developing negative emotions towards changes in their body weight. Blind weight loss and inaction can lead to both underweight and obesity, which are adverse effects. Therefore, schools should actively carry out mental health work, provide counseling to adolescents with body image anxiety, help them form correct body image cognition, encourage them to participate in sports activities, and reduce the impact of negative emotions.

Declarations

Ethics approval and consent to participate

The present study strictly adhered to the principles of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards, and had been also in accordance with relevant ethics standards of the Ethics Review Committee from South China University of Technology (grant number: SCUT-SPT-2022-003). And before formally participating in this survey, all participants provided their written informed consent, prior to the formal data collection (A minor aged 16 has obtained written consent from both their parents or legal guardians).

Consent for publication

Agree to publish.

Competing Interests

The authors declare that no any conflicts of interest.

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Author Contribution

Yulituzeayi Maitituersun: Draw the first draft, organize and analyze the data, and create charts. Su ran: Organize data and references, adjust the article's format. Guan Yang: Conceptualization, supervision, validation, fund acquisition, review and editing. Alimujiang Yimiti Taerken: Supervision; validation; conceptualization; investigation; project administration; resources; writing—review and editing.

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Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Figures

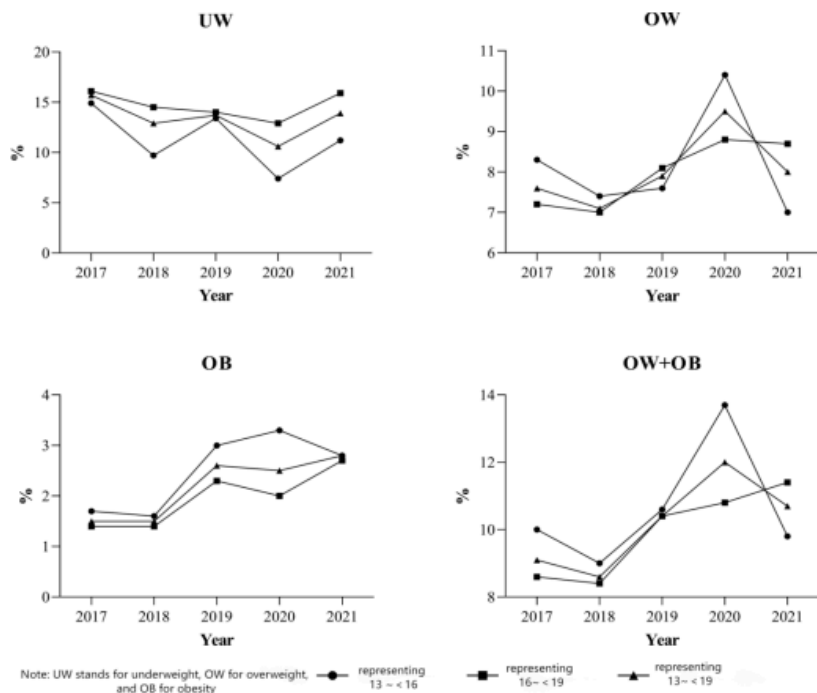


Figure 1

Prevalence of different physical status in adolescents of different age groups from 2017 to 2021

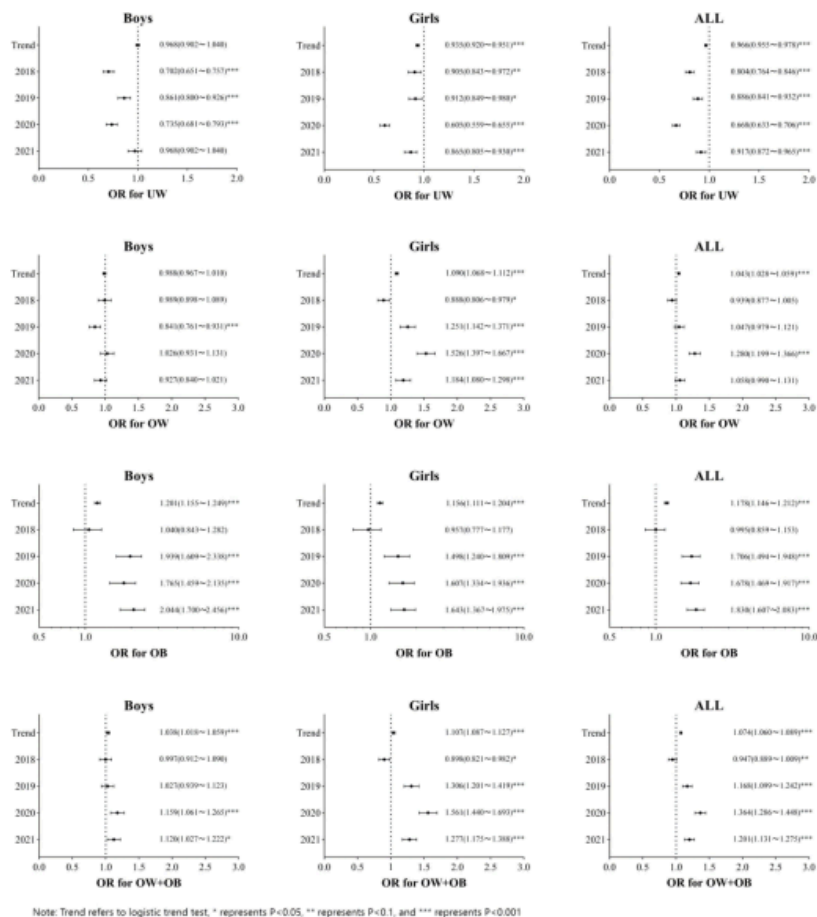


Figure 2

Logistic regression analysis of nutritional status of adolescents aged 13-18 in China from 2017 to 2021