


# BMJ Open Weight gain in Chinese youth during a 4-month COVID-19 lockdown: a retrospective observational study

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## ABSTRACT

**Objectives** To observe the weight change in Chinese youth during a 4-month COVID-19 lockdown, and the association between weight change and mental health, physical activity and sedentary time changes, and dietary habits.

**Design** A retrospective observational study.

**Settings** Two universities located in Zhejiang and Hunan provinces, China.

**Participants** This study enrolled 12 889 college students whose body weight was measured before the lockdown (1 December 2019–20 January 2020) at the two universities, and reported their weight measured at home or community after the end of the lockdown (1–23 May 2020) via an online follow-up questionnaire.

**Primary and secondary outcome measures** The primary outcome was the weight change in Chinese youth during a 4-month lockdown resulting from the COVID-19 pandemic. The secondary outcomes were the relationships of weight change to COVID-19-related stress, depression, anxiety, physical activity and sedentary time changes, and dietary habits.

**Results** Participants' ages ranged from 17 to 27 years ( $M=19$ ,  $SD=1$ ) with 80.2% identified as female. The average absolute and relative changes in body weight were 2.6 (95% CI 2.0 to 3.2) kg and 4.2% (95% CI 4.0% to 4.3%) for men, and 2.1 (1.9 to 2.4) kg and 4.2% (95% CI 3.9% to 4.4%) for women. An increase in overweight and obese individuals according to Asian cut-off points as a demographic percentage by 4.5% and 2.7% and 4.8% and 3.4% in men and women, respectively ( $P<0.001$ ), was observed. Weight gain was significantly associated with increased sedentary time and an increase in COVID-19-related stress and depression score.

**Conclusion** The present study's results suggest that the risk of weight gain in Chinese youth during the lockdown increased and that strategies to decrease sedentary time and improve mental health may be warranted to mitigate weight gain during and after the COVID-19 pandemic.

## INTRODUCTION

The sudden emergence of COVID-19 has reverberated the world over, pushing peoples and governments into the uncharted territories of countrywide lockdowns and social distancing. On 20 January 2020, China issued a national

## Strengths and limitations of this study

- The occurrence of weight gain during a 4-month lockdown due to the COVID-19 pandemic was observed in a population of 12 889 Chinese youth.
- This study provides evidence for the associations between weight gain and increased sedentary time, COVID-19-related stress and depression score throughout a 4-month lockdown.
- The methods of collecting body weight in the two time periods differed, with the first being under the supervision of professionals, the second being self-administered due to the constraints of lockdown.

lockdown to halt the spread of the virus, ending on 8 April. All individuals were ordered to stay home or at their residence, except for permitted work and local shopping. All schools, sports facilities, entertainment, recreational venues, personal care and beauty services, and most factories and markets were closed. While this strategy was largely successful, its adverse effects could be of consequence to the health of youth, as for 4 months, they were out of school and, for the most part, stuck in the confines of their homes.<sup>1</sup>

Weight gain during adolescence and early adulthood is associated with a significantly increased morbidity of diabetes and cardiovascular disease, and an increased risk of cardiovascular and all-cause mortality.<sup>2,3</sup> The increase in weight is a multifactorial matter. Long-term observational studies and randomised controlled trials have found dietary factors, sedentary behaviours and time spent watching TV were associated with long-term weight gain in healthy populations.<sup>4,5</sup>

Early evidence has shown that lockdown poses a real threat to psychological well-being, with research citing amplified stress and depression during the COVID-19 pandemic.<sup>6,7</sup> Furthermore, in certain countries, there has been a surge in unhealthy

dietary habits and increased sedentary time, which could be a recipe for increased weight gain.<sup>8–10</sup> Staying at home for a prolonged period could also support a more sedentary lifestyle and increased time watching TV or other electronic entertainment, along with eating more calorie-dense meals, snacking and alcohol consumption. To date, an increasing number of studies have been conducted related to weight change and its associated factors during the COVID-19 lockdown period in various populations, primarily in Europe, and some of those have suggested that behaviour change during the pandemic is a driving force behind weight change.<sup>8,9</sup>

This dual-centre retrospective observational study aimed to observe weight change in Chinese youth during a 4-month lockdown and the associations between weight change and COVID-19-related stress, anxiety, depression, physical activity, sedentary time and dietary habits.

## MATERIALS AND METHODS

### Study design and participants

This retrospective observational study reviewed 14059 youth (aged 17–27 years) free of chronic diseases from two universities (Hunan Traditional Chinese Medical College, Hunan, China, and Medical College of Jinhua Polytechnic, Zhejiang, China) who measured body weight at the universities before the lockdown, between 1 December 2019 and 20 January 2020. Of these, 13013 participants (response rate of 93.2%) consented to participate in the present study and completed an online follow-up questionnaire from 1 to 23 May 2020. The participants who replied with questionnaires of poor quality were excluded (n=124). A total of 12889 participants were finally recruited in the study. The criteria of poor quality were as follows: (1) identity (ID) information in the universities' system did not match that in the follow-up questionnaire, and (2) the 81-question survey was completed in less than 3 min. Data from the two time points were linked by identifying each participant's university student ID number and matching them accordingly.

### Online follow-up questionnaire

The online follow-up questionnaire consisted of 81 questions split into four sections: questions regarding characteristic data and perceptions of COVID-19, a questionnaire regarding physical activity and sedentary time, a section regarding meal frequency and alcohol consumption, and questions to assess mental health. The online follow-up questionnaire was sent out to participants and collected via a professional survey platform (<https://www.wjx.cn>).

### Weight change

Baseline body weight was measured in accordance with the Chinese National Student Physical Fitness Standard by staff members of the two respective universities for all university students,<sup>7</sup> using scales and after the removal of shoes/coats, while height was measured using a free-standing height measure. Body mass index (BMI) was

calculated and classified according to the Asian cut-off points, classifying overweight as BMI of  $\geq 24$  and  $< 28$  kg/m<sup>2</sup>, and obesity as BMI of  $\geq 28$  kg/m<sup>2</sup>. Follow-up body weight was measured by participants themselves at home or at a community health centre near their home if no scales were available at home, and was reported to us via the online follow-up questionnaire. Concerning the validity and reliability of determining follow-up body weight, all participants were asked to measure their body weight in the morning right after waking up, in a state of fasting, shoes off, with no large coat. Weight change was calculated by subtracting baseline weight from follow-up weight. Previous studies commonly categorised weight gain as an increase greater than 5% of body weight from baseline, 10% for greater increases,<sup>11</sup> or categorised weight gain as an increase of approximately 3 kg above baseline.<sup>12,13</sup> Based on our study population with a mean baseline body weight of  $52.3 \pm 9.5$  (mean  $\pm$  SD), weight change was classified as no significant change ( $-0.9$  to  $0.9$  kg), mild decrease ( $-3.9$  to  $-1.0$  kg), moderate decrease ( $-6.9$  to  $-4.0$  kg), major decrease ( $\leq -7.0$  kg), mild increase ( $1.0$  to  $3.9$  kg), moderate increase ( $4.0$ – $6.9$  kg) and major increase ( $\geq 7.0$  kg).

### Physical activity and sedentary time

Physical activity and sedentary time were collected through questions regarding exercise prelockdown and during lockdown. These included frequency, duration and intensity of aerobic exercise as well as strength exercise, in a modified version with added items of the Chinese version of the International Physical Activity Questionnaire—Long Form, which had shown adequate reliability and reasonable validity for use in Chinese students.<sup>14</sup> Exercise volume was expressed in Metabolic equivalent (MET)-hour/week, calculated according to the American College of Sports Medicine (ACSM) metabolic equations prior to and during the lockdown.<sup>15</sup> Sedentary time, defined as any waking behaviour where energy expenditure is  $\leq 1.5$  METs while reclining or sitting, included the number of hours a day spent using a computer or mobile phone<sup>15</sup> and was expressed as hour/day. The changes in exercise volume per day and sedentary time per week over the 4-month lockdown were calculated.

### Dietary habits

In this study, food composition was not assessed due to the high participant burden of such a questionnaire and data collection limitations. The present study evaluated meal frequency, including breakfast and lunch frequency, alcohol units per week and snacking times per day at the follow-up time point through a questionnaire based on previous research.<sup>16</sup> Breakfast and lunch frequency were categorised into three groups: less than once a week, two to six times per week and every day. Snacking was also categorised into three groups: no snacking, snacking once a day (day or late-night) and snacking twice per day (day and late-night). Alcohol habits were recorded as the number of alcohol units. One unit was defined as

drinking 100 mL of wine or liquor or one glass/bottle/can of beer.

### Mental health (COVID-19-related stress, depression and anxiety)

The question used to measure COVID-19-related stress was designed based on previous research<sup>17</sup>: how concerned are you about yourself or family members/friends being infected by COVID-19? To which the possible answers were none, mild, moderate, major and severe. Two psychological indexes were also used, Becks' Depression Inventory, Second Edition (BDI-II),<sup>18</sup> validated in young Chinese adults,<sup>19 20</sup> and the State-Trait Anxiety Inventory (STAI) (Form Y-1),<sup>21</sup> showing good reliability and validity in Chinese.<sup>22</sup> In this study, the presence of depression was defined as a BDI-II depression score of  $\geq 14$ ,<sup>20</sup> and the presence of anxiety was defined as an STAI score of 49.<sup>22</sup>

### Statistical analysis

The primary outcome of the present study was weight change in Chinese youth during a 4-month lockdown to contain the spread of the COVID-19 pandemic. The secondary outcomes were the associations between the weight change and mental health (COVID-19-related stress, depression and anxiety), changes in physical activity volume and sedentary time, and dietary habits (snacking per day, alcohol consumption and meal frequency per week) during the lockdown.

For analysis of the primary outcome, the changes in body weight, proportions of overweight and obesity were

assessed using paired t-test and Wilcoxon signed-rank test accordingly.

For analysis of the secondary outcomes, we initially performed an age-adjusted and baseline body weight-adjusted linear regression for the associations between the weight change and mental health, dietary habits, and the changes in physical activity and sedentary time. Then, the associations between the weight change and the potential influencing factors were further assessed by multivariate linear regression in which sex, age, baseline body weight and smoking history were adjusted. Mental health, physical activity, sedentary time and dietary habits were also adjusted in the multivariate linear regression accordingly. To minimise confounding from university (geolocation) and baseline overweight/obesity, university-stratified and BMI-stratified multivariate linear regressions were also performed. Analyses were carried out with the use of SAS software V.9.4; a two-tailed alpha level of 0.05 was considered significant.

### Patient and public involvement statement

No patients or the public were involved in the design, or conduct, or reporting of our research.

## RESULTS

### Demographics

The demographics of 12 889 participants are presented in [table 1](#). Participants' ages ranged from 17 to 27 years ( $M=19$ ,  $SD=1$ ), 80.2% identified as female. The proportion

**Table 1** Demographics and baseline characteristics

	University 1 (N=9472)*		University 2 (N=3417)*		Total (N=12 889)	
	Men (N=1509)	Women (N=7963)	Men (N=1040)	Women (N=2377)	Men (N=2549)	Women (N=10 340)
Age (years)	19±1	19±1	20±1	20±1	20±1	19±1
Weight (kg)	62.3±10.2	52.0±7.8	65.0±10.3	52.2±7.6	63.4±10.3	52.0±7.7
BMI (kg/m <sup>2</sup> )	21.0±3.2	20.3±2.7	21.4±3.1	20.1±2.5	21.2±3.2	20.2±2.7
Overweight, n (%)†	214 (14.5)	1370 (17.2)	83 (8.0)	140 (5.9)	297 (11.7)	1510 (14.6)
Obesity, n (%)†	57 (3.8)	263 (3.3)	17 (1.6)	36 (1.5)	74 (2.9)	299 (2.9)
Race/ethnicity, n (%)						
Han	1305 (86.5)	6872 (86.3)	1040 (100)	2377 (100)	2345 (92.0)	9249 (89.4)
Non-Han	204 (13.5)	1091 (13.7)	0 (0)	0 (0)	204 (8.0)	1091 (10.6)
Physical activity (MET-hour/week)	14.2±12.5	9.1±8.5	13.7±12.2	7.7±7.3	14.0±12.3	8.9±8.3
Sedentary time (hour/day)	6.9±3.4	7.3±3.4	7.0±3.2	7.3±3.3	6.9±3.3	7.3±3.4
Smoking, n (%)						
Currently smoking	294 (19.5)	77 (1.0)	96 (9.2)	9 (0.4)	390 (15.3)	86 (0.9)
<10 cigarettes/day	220 (14.6)	66 (0.8)	77 (7.4)	7 (0.3)	297 (11.7)	73 (0.7)
10–15 cigarettes/day	45 (3.0)	8 (0.1)	12 (1.1)	1 (0.04)	57 (2.2)	9 (0.09)
>15 cigarettes/day	29 (1.9)	3 (0.1)	7 (0.7)	1 (0.04)	36 (1.4)	4 (0.03)
Former smoker	165 (10.9)	130 (1.6)	62 (6.0)	17 (0.7)	227 (8.9)	147 (1.4)
Never smoke	1050 (69.6)	7756 (97.4)	882 (84.8)	2351 (98.9)	1932 (75.8)	10 107 (97.7)

Data are expressed as mean±SD or number (per cent) accordingly. Results were assessed by paired t-test and Wilcoxon signed-rank test accordingly.

\*University 1 is Hunan Traditional Chinese Medical College, Hunan province, China; university 2 is Jinhua Polytechnic, Zhejiang province, China.

†Overweight and obesity cut-off points were referred to Asian criteria; overweight is BMI  $\geq 24$  and  $< 28$  kg/m<sup>2</sup>, and obesity BMI  $\geq 28$  kg/m<sup>2</sup>. BMI, body mass index.



of men in the present study is relatively smaller than that of women. We conducted power analysis based on the sample size and primary result (weight change) in the present study for men and women, respectively. For men, a sample size of 2549 achieves 99.9% power to detect a mean of paired differences of 2.6 kg with a known SD of differences of 0.6 kg and a significance level (alpha) of 0.05 using a two-sided paired t-test. For women, a sample size of 10 340 achieves 99.9% power to detect a mean of paired differences of 2.1 kg with a known SD of differences of 0.3 kg.

### Primary outcome

The median of the subjects' baseline body weight was 62.0 kg, ranging from 39.0 to 95.0 kg (lowest to highest) in men, and 50.1 kg, ranging from 38.5 to 92.0 kg in women. The mean absolute and relative changes in weight gain were 2.6 (95% CI 2.0 to 3.2) kg and 4.2% (95% CI 4.0% to 4.3%) for men, and 2.1 (95% CI 1.9 to 2.4) kg and 4.2% (95% CI 3.9% to 4.4%) for women, while those in the overall population were 2.2 (95% CI 2.0 to 2.5) and 4.2% (95% CI 4.0% to 4.3%). There was a significant increase in overweight and obese individuals as a percentage of the population by 4.5% and 2.7% in men, and 4.8% and 3.4% in women. According to their self-reports, none of the participants of the study was infected with COVID-19. More details are shown in [figure 1A–E](#) and online supplemental table 1.

### Secondary outcomes

#### Associations between weight change and the changes in physical activity and sedentary time

Sedentary time before the lockdown was 6.9±3.3 and 7.3±3.4 hours/day in men and women, respectively. There were significant increases in sedentary time in both men (3.9 (95% CI 3.7 to 4.1) hours/day) and women (3.6 (95% CI 3.5 to 3.7) hours/day). Exercise volume per week before the lockdown was 14.0±12.3 and 8.9±8.3 MET-hr/wk in men and women, respectively. There was a decrease in men (mean -0.6, 95% CI -1.1 to -0.1) and an increase in women (mean 2.5, 95% CI 2.3 to 2.7). More details are shown in [figure 1F,G](#) and online supplemental table 1.

Linear regression results for associations between the weight change and the changes in physical activity and sedentary time are presented in [tables 2 and 3](#). Findings were comparable in direction and magnitude after stratification for BMI of <24 and ≥24 kg/m<sup>2</sup> and two universities (online supplemental tables 2,3). Categorical analyses of sedentary time revealed similar linear relationships; that is, aggregate change in sedentary time was significantly associated with weight gain in a dose-dependent fashion, with a 1.56 kg greater weight gain across quartiles ([figure 2](#)). The results were consistent when results were evaluated as relative (per cent) weight changes (online supplemental table 4).

#### Associations between weight change and dietary habits

Men (1.8±2.9 alcohol units) drank more than women (0.7±1.6 alcohol units). The mean difference was 1.2 (95% CI 1.1 to 1.3). In contrast, the proportion of women who ate snacks at least once per day was significantly greater than men (women vs men, 87.9% vs 83.2%,  $p<0.001$ ). Only 33.9% of men and 32.2% of women had breakfast every day. No significance was found between men and women ( $P=0.19$ ). In contrast, 98.4% of men and 98.6% of women had lunch every day. More details about participants' dietary habits during a 4-month lockdown are shown in online supplemental table 5. In the multivariate linear regression, no significant associations were found between weight change and dietary habits.

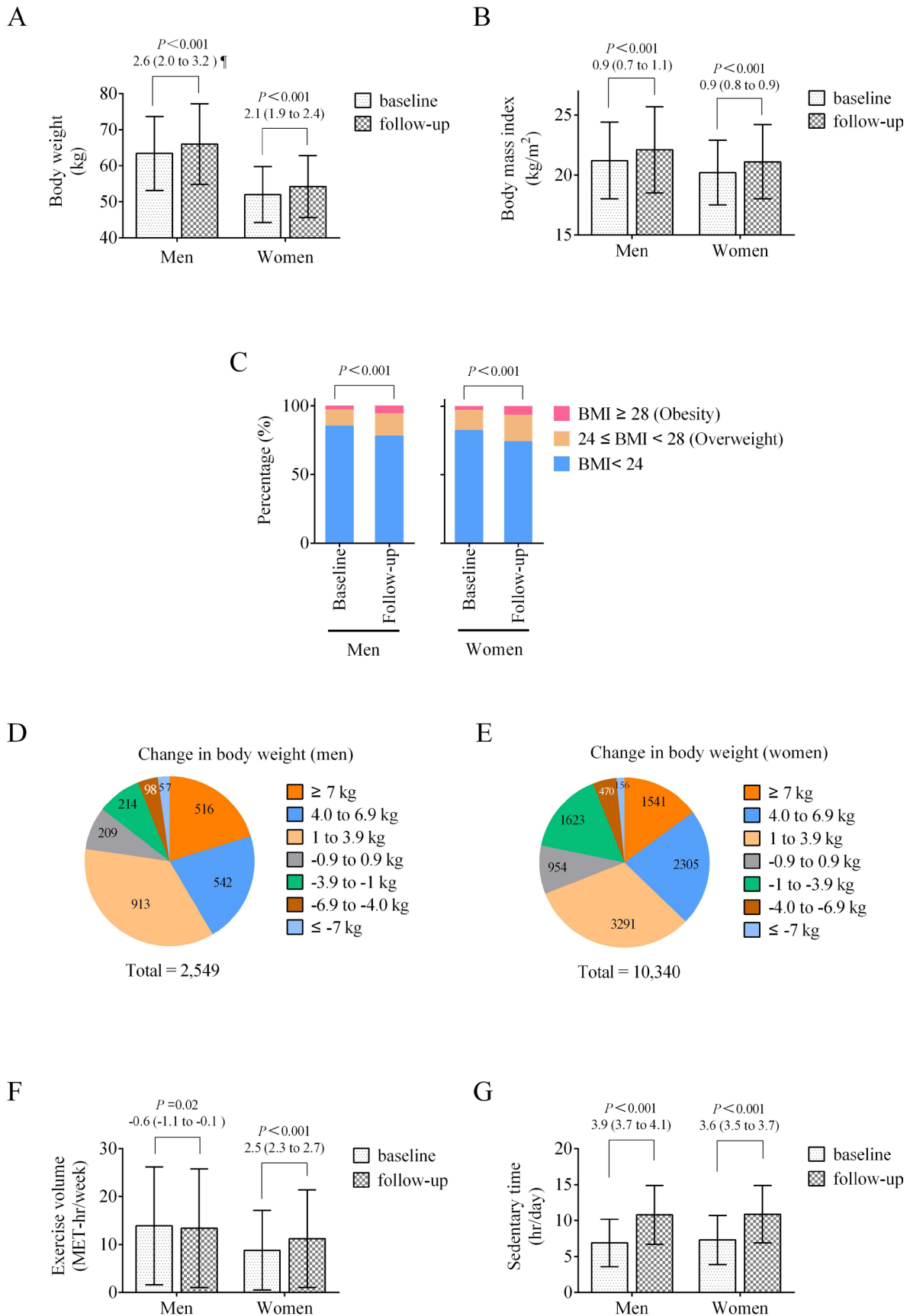
#### Associations between weight change and mental health

More than one-third of all participants (34.6% of men and 42.4% of women) suffered from COVID-19-related stress in different degrees, and 6.9% of men and 7.4% of women responded to having severe stress. The depression score obtained from BDI-II was 5±8 (mean±SD) and 6±8 in men and women, respectively. Here the STAI anxiety score was 39±10, both in men and women. More details about participants' mental health during the 4-month lockdown are shown in online supplemental table 5. Increased COVID-19-related stress and BDI-II depression score were significantly associated with weight gain. Detailed results are presented in [tables 2 and 3](#) and [figure 2](#). Findings were comparable in direction and magnitude after stratification for BMI and two universities (online supplemental tables 2,3), and were also similar when evaluated as relative weight changes (online supplemental table 4).

## DISCUSSION

Longitudinal studies have shown that the average yearly weight gain in general populations is approximately 0.45 kg a year.<sup>4</sup> This study observed a significant weight gain, an increase of 2.2 (95% CI 2.2 to 2.3) kg, over a 4-month lockdown period in Chinese youth. A sharp increase in weight has been associated with an increase in blood pressure.<sup>23</sup> Even more moderate increases over a longer period are associated with chronic diseases,<sup>24</sup> all of which are exacerbated when weight is gained during adolescence and early adulthood to have later life repercussions.<sup>25 26</sup> The interruption of individual routines and confinement may lead to a calorie imbalance pushed by concomitant lower physical activity and increased sedentary time, as well as irregular eating patterns and frequent snacking. This study provides evidence for the associations between weight gain and increased sedentary time, COVID-19-related stress and depression score over the span of a 4-month lockdown.

Limited mobility of the general public, as a consequence of lockdowns around the world, has yielded undesired effects of more prevalent sedentary behaviour<sup>27</sup> that comprise very little calorific demand.<sup>28</sup> Sedentary time in



**Figure 1** Changes in body weight (A), BMI (B), the proportion of overweight and obesity (C), weight gain as a proportion in men (D) and women (E), exercise volume per week (F) and sedentary time per day (G) over the 4-month lockdown. The line indicates the mean, and the error bar indicates the SD. The results were assessed by paired t-test and Wilcoxon signed-rank test were used accordingly. †Mean difference and 95% CI. BMI, body mass index.

**Table 2** Age-adjusted and baseline body weight-adjusted linear regression for the associations between weight change and mental health, dietary habits and the changes in physical activity to weight change during the 4-month lockdown

	Men (N=2549)		Women (N=10340)		Total (N=12889)	
	Coefficient (95% CI)	P value	Coefficient (95% CI)	P value	Coefficient (95% CI)	P value
Psychological status						
COVID-19-related stress*						
None	Reference		Reference		Reference	
Mild	0.450 (-0.075 to 0.975)	0.12	0.153 (-0.069 to 0.375)	0.30	0.192 (-0.013 to 0.398)	0.08
Moderate	-0.004 (-0.774 to 0.767)	0.99	0.282 (-0.050 to 0.614)	0.13	0.225 (-0.080 to 0.532)	0.24
Major	0.551 (-0.449 to 1.551)	0.52	0.339 (-0.074 to 0.752)	0.15	0.362 (-0.022 to 0.746)	0.07
Severe	1.116 (0.339 to 1.892)	0.001	0.521 (0.176 to 0.865)	<0.001	0.619 (0.303 to 0.935)	<0.001
Depression score	0.034 (0.015 to 0.052)	<0.001	0.024 (0.015 to 0.032)	<0.001	0.025 (0.017 to 0.033)	<0.001
Anxiety score	0.014 (-0.001 to 0.029)	0.08	0.011 (0.004 to 0.018)	0.003	0.012 (0.005 to 0.018)	<0.001
Changes in physical activity (MET-hour/week)	-0.003 (-0.015 to 0.008)	0.59	-0.007 (-0.014 to 0.000)	0.04	-0.008 (-0.002 to -0.013)	<0.001
Sedentary time (hour/day)	0.504 (0.466 to 0.542)	<0.001	0.457 (0.440 to 0.475)	<0.001	0.468 (0.452 to 0.484)	<0.001
Dietary habits						
Alcohol (drinks/week)	0.023 (-0.029 to 0.075)	0.38	-0.072 (-0.115 to -0.028)	<0.001	-0.017 (-0.049 to 0.016)	0.31
Snacking*						
No	Reference		Reference		Reference	
Day or late-night	0.189 (-0.303 to 0.680)	0.57	0.391 (0.143 to 0.639)	0.001	0.302 (0.082 to 0.523)	0.005
Day and late-night	0.383 (-0.101 to 0.867)	0.14	0.456 (0.205 to 0.707)	<0.001	0.410 (0.187 to 0.633)	<0.001
Breakfast (frequency/week)*						
Less than once	Reference		Reference		Reference	
Two to six	-0.005 (-0.574 to 0.564)	0.99	0.514 (0.252 to 0.775)	<0.001	0.415 (0.176 to 0.654)	<0.001
Every day	0.131 (-0.466 to 0.728)	0.80	0.813 (0.536 to 1.090)	<0.001	0.685 (0.433 to 0.937)	<0.001
Lunch (frequency/week)*						
Less than once	Reference		Reference		Reference	
Two to six	1.521 (0.188 to 2.853)	0.02	0.473 (-0.152 to 1.100)	0.14	0.644 (0.076 to 1.214)	0.03
Every day	1.07 (-0.223 to 2.361)	0.11	0.535 (-0.079 to 1.151)	0.09	0.648 (0.092 to 1.206)	0.02

Data are expressed as weight change in kilogram related to each variable. Results were evaluated via multivariate linear regression.

\*For COVID-19-related stress, snacking, breakfast and lunch frequency/week during the lockdown, the first level of the ordered categorical variables were used as reference.

**Table 3** Multivariate linear regression for the associations between weight change and COVID-19-related stress, depression score and the change in sedentary time during the 4-month lockdown

	Men (N=2549)		Women (N=10340)		Total (N=12889)	
	Coefficient (95% CI)	P value	Coefficient (95% CI)	P value	Coefficient (95% CI)	P value
COVID-19-related stress*						
None	Reference		Reference		Reference	
Mild	0.184 (−0.309 to 0.677)	0.82	−0.035 (−0.239 to 0.170)	0.99	−0.015 (−0.205 to 0.176)	0.99
Moderate	−0.320 (−1.063 to 0.423)	0.73	0.049 (−0.259 to 0.356)	0.99	−0.025 (−0.310 to 0.261)	0.99
Major	0.213 (−0.720 to 0.146)	0.96	0.039 (−0.341 to 0.418)	0.99	0.056 (−0.298 to 0.409)	0.99
Severe	0.878 (0.149 to 1.607)	0.01	0.493 (0.130 to 0.816)	<0.001	0.551 (0.254 to 0.847)	<0.001
Change in sedentary time (hour/day)	0.530 (0.490 to 0.571)	<0.001	0.463 (0.446 to 0.481)	<0.001	0.476 (0.460 to 0.492)	<0.001
Depression score	0.023 (0.001 to 0.047)	0.04	0.019 (0.008 to 0.030)	0.001	0.017 (0.007 to 0.027)	0.001

Data are expressed as weight change in kilogram related to each variable. Results were evaluated via multivariate linear regression.

\*For COVID-19-related stress, no stress was a reference.

our population of Chinese youth increased and was associated with increased weight. These findings are consistent with prior research showing sedentary behaviour, TV viewing and computer use being risk factors for the increased weight<sup>29 30</sup> and consistent with similar observations in Europe.<sup>31</sup> A possible reason behind this may be due to the general restraint to one's home and the greater availability of free time without requiring active travel to school/work. In addition, increased sedentary time is likely due to a combination of boredom, free time, distance learning and online social activity.<sup>31</sup>

In the present study, exercise volume was associated with weight change in women alone, possibly due to the low exercise volume both before and during the lockdown, far below the ACSM-recommended exercise volume (16.7 MET-hours/week),<sup>15</sup> and the change in exercise volume in the overall population being small. Various studies have looked into physical activity. While there is some disagreement within population cohorts, in university students, exercise habits are largely mediated by time constraints,<sup>32</sup> where students perceive limited time as a primary reason for not exercising. Also, adherence to exercise is often extrinsic, particularly in youth, where exercisers do so because of physical appearance, weight gain and stress management, adding plausibility that exercise may have been increased as management for perceived weight gain and/or stress and due to more available time. Exercise, particularly high-intensity interval training, can bring about great improvements in reducing body fat, improving body composition<sup>33</sup> and reductions in associated health complications including metabolic syndrome and insulin resistance,<sup>34 35</sup> and therefore is an activity that is encouraged, particularly during the lockdown.

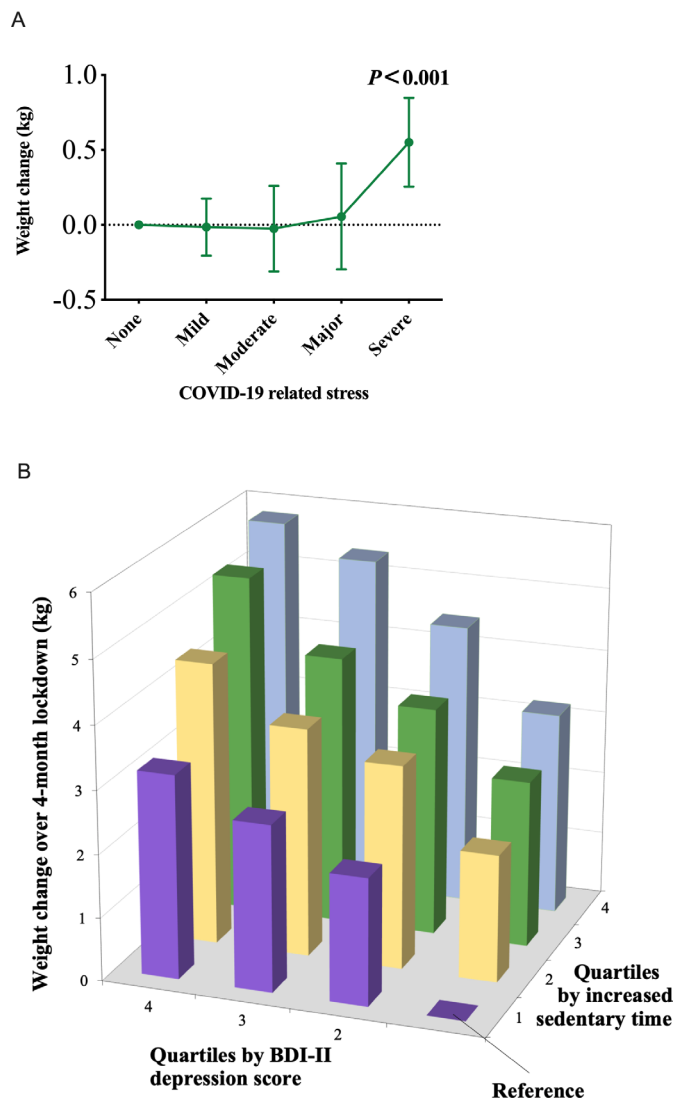
Weight gain also comes through increased intake of calorie-rich food, large portions and dependent on food composition,<sup>36</sup> leading to weight gain. The COVID-19 pandemic may pose a notable dietary risk exacerbated by the confinement to the home for a prolonged period, often with greater access to food. Across multiple populations

around the world, there have been studies showing significant changes in dietary habits during the lockdown. In the UK, as many as 48% of research participants reported increased food intake<sup>37</sup> and increased detrimental dietary practices, echoed throughout the world,<sup>38 39</sup> with research reporting an increase in snacking and eating in response to smell and sight.<sup>10</sup> Increased problematic eating behaviours such as increased snacking, as seen in the present study, may result in an increase in fat mass and percentage due to higher calorie intake. This study observed that snacking frequency per day was positively related to weight gain in women alone.

COVID-19 lockdowns can greatly affect the social environment of youths. According to Androutsos *et al*<sup>31</sup> 5.1% of mothers and 2.9% of fathers of those surveyed in Greece had lost their jobs, which could affect stress levels of the immediate family. In addition, during the initial lockdown, the continuous hearing and constant news coverage on the spread of COVID-19 and mortality associated with it can be stressful.<sup>40</sup> Since then, evidence has been accumulating that lockdown conditions have increased the prevalence of depression, anxiety and stress across multiple populations.<sup>41 42</sup> Stressful life events, such as university/school-related stress, are known to be associated with weight gain.<sup>43</sup> We found that severe stress over COVID-19 was associated with considerable weight gain in women and men. During this pandemic, a significantly high percentage of survey respondents reported increased eating as a response to stress and sleep deprivation during the quarantine, as reported by Zachary *et al*.<sup>10</sup> In various people, the manifestation of stress or an emotional disturbance may lead to a resulting coping mechanism of increasing the consumption of energy-dense foods.<sup>44</sup> Stress is also thought to affect PA. A comprehensive review found the majority of 55 longitudinal studies supported an association between stress and lower levels of PA.<sup>45</sup>

Social isolation and confinement are possible routes towards depression.<sup>46</sup> BDI-II depression score was associated with increased weight gain. This is in agreement





**Figure 2** (A) The relationship between COVID-19-related stress and weight change;  $p < 0.001$  for comparison between no stress and severe stress was assessed by Wilcoxon signed-rank test. (B) The relationship between the cross-stratified quartiles of changes in sedentary time and depression score in ascending order with weight changes. As compared with individuals in the lowest quartiles of both sedentary time and depression score, individuals in the highest quartiles had a 5.82 kg greater weight gain ( $P < 0.001$ , 95% CI 5.37 to 6.27), evaluated via multivariate linear regression.  $P < 0.001$  for all comparisons. BDI-II, Beck's Depression Inventory, Second Edition.

with a consortium of previous studies whereby depression appears to have a significant effect on short-term and long-term weight gain.<sup>47 48</sup> Anxiety was a minimal contributor to weight gain in women, but not in men, and appears to be more commonly present in women, which supports previous studies that state anxiety appears to affect women during the pandemic more than men.<sup>49</sup> While stress and depression may affect sedentary behaviour, these relationships are likely bidirectional, whereby an increase in sedentary behaviour may also increase stress elements and depression.

## Limitations

There are several limitations to this study. The methods of collecting weight in the two time periods differed, with the first being under the supervision of professionals and the second being self-administered due to the constraints of lockdown. While instructions were given to participants regarding how and when to weigh themselves, measurement errors as well as overestimation/underestimation may occur to some degree. Although breakfast and lunch frequency, snacking and alcohol intake were observed, this study did not report on dietary composition due to the heavy burden on participants, particularly in Chinese cuisine, which involves several dishes per meal. Due to limitations in research, we have no data representative of yearly or semesterly weight gain in Chinese university students to compare our results with. Psychological status of depression and anxiety was collected at the second time point only; therefore, causality may not be established from these.

Furthermore, just as with any medical intervention or organic finding, the results represent the average public effect, and variations within individuals exist. The present retrospective study only observed a 4-month lockdown that resulted from the COVID-19 pandemic, and primarily comprised Han, university-educated Chinese youth, which potentially limited the generalisability of the findings. However, our findings were consistent among two universities, sex and individuals with BMI of  $< 24$  and  $\geq 24$  kg/m<sup>2</sup>, with multivariable adjustment. All results remained persistent in additional analyses when weight change was evaluated as relative weight changes. It seems plausible that the biological effects of many factors would be qualitatively similar in other populations.

## CONCLUSION

There was a significant weight gain in the Chinese youth during a 4-month lockdown. The weight gain was associated with increased sedentary time, COVID-19-related stress and depression. These findings suggest that interventions to decrease sedentary time and improve mental health may be warranted to mitigate weight gain during the lockdown period and reverse the weight gain in youth after the COVID-19 pandemic.

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