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Independent and combined associations between multiple lifestyle behaviours and academic grades of inner urban and peri-urban high school students: a cross-sectional study in Chongqing, China

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ABSTRACT

Objectives This study aims to assess the independent and combined associations between multiple lifestyle behaviours and academic grades of inner urban high school students (IUHSSs) and peri-urban high school students (PUHSSs).

Design A cross-sectional study was conducted.

Participants There are 1481 high school students (49.9% boys) in this study, who were enrolled from one inner urban and two peri-urban schools in Chongqing, China.

Outcome measures Academic grades were assessed based on the students' self-reported grade ranking in the last cumulative examination.

Results In IUHSSs and PUHSSs, high frequency of sugar-sweetened beverage consumption was unlikely to obtain high academic grades (OR 0.56, 95% CI 0.32 to 0.99 and 0.63, 95% CI 0.42 to 0.96), respectively). Among IUHSSs, meeting the recommendations for weekday screen time and egg consumption (OR 1.57, 95% CI 1.06 to 2.34 and 1.60, 95% CI 1.04 to 2.47, respectively) and high frequency of fruit consumption (1.67, 95% CI 1.11 to 2.50) were significantly associated with high academic grades; meeting the recommendation for weekday sleep duration was unlikely to obtain high academic grades (0.46, 95% CI 0.21 to 0.98). Among PUHSSs, meeting the recommendations for weekend sleep duration (1.40, 95% CI 1.02 to 1.93) and eating dinner regularly (1.55, 95% CI 1.01 to 2.37) had significant associations with high academic grades. No significant associations were found between physical activity and academic grades in both IUHSSs and PUHSSs (p>0.05). Moreover, IUHSSs with 9–13 healthy lifestyle behaviours were 3.25 times more likely to achieve high academic grades than IUHSSs with 1–6 healthy lifestyle behaviours (3.25, 95% CI 1.96 to 5.40). No significant associations were found in the combined associations between multiple lifestyle behaviours and academic grades among PUHSSs (p>0.05).

Conclusions Correlations were observed between lifestyle behaviours and academic grades among high school students, and cumulative associations between multiple healthy lifestyle behaviours and academic outcomes appear to be stronger than the independent

Strengths and limitations of this study

► This study is novel as the independent and combined associations between multiple lifestyle behaviours and academic grades among Chinese high school students were assessed.

► Study participants included inner urban and peri-urban Chinese students, the results in this study could be generalisable to other settings with economic disparities.

► Self-reported data such as lifestyle behaviours and academic grades may result in social desirability bias.

► Unvalidated measures in the questionnaire may raise potential issues related to reliability.

► The cross-sectional nature of this study limits the assessment of causality.

associations. These findings are particularly applicable to IUHSSs.

INTRODUCTION

High school is a key stage in students' transition to college, academic grades of high school students are closely related to college or university admission, even their future careers and health in adulthood.[1] A better understanding of modifiable factors affecting high school students' academic grades is important for public health researchers and school principals or management bodies in the high school settings.

Healthy lifestyles, including healthy dietary behaviours, sufficient physical activity and sleep, minimal screen time, etc, are positively associated with students' academic performance.[2–4] Studies examining the associations between dietary behaviours and academic achievement have typically focused on micronutrient intake,[5] dietary

intakes[6] and breakfast consumption.[2] [7] Intake of certain micronutrients (ie, iron), high frequency of fruit and vegetable consumption, low consumption of energy-dense and nutrient-poor food, and regular breakfast consumption all predict the likelihood of good academic grades.[5] [7–9] Current studies on the association between physical activity and academic grades of children and adolescents are inconsistent. With reported evidence of exercise affecting cognition,[10] the positive influence of appropriate physical activities on the academic grades of children and adolescents is observed.[4] [11] However, some studies have reported that additional or enhanced physical exercise do not show positive results in improving academic grades.[12] [13] Previous studies investigated the correlation between poor sleep quality and reduced learning capability and poor academic grades among children and adolescents.[14] [15] Studies on the correlation between students' screen time and their academic performance have shown that spending considerable time on television, videos or social networking sites appears to be negatively associated with academic grades.[16] [17]

Previous studies mainly focused on the association between a single lifestyle factor and students' academic grades.[2] [3] [16] [18] However, some scholars have proposed that the relationship between healthy lifestyle behaviours and academic performance is not isolated, and the combined associations between multiple healthy lifestyle behaviours and academic performance may be greater than any single behaviour alone.[19–21] Ickovics et al found that children in grades 5–6 with higher levels of 'health assets' including indicators of a healthy diet, physical activity, screen time and sleep, are two times higher to meet the goal of standardised exams.[22] Faught et al found that grade 5 students who met the recommendations for 7–9 lifestyle behaviours have higher odds of meeting the expectations for academic achievement compared with those who met three or fewer recommendations.[23] With the social, cultural and educational context of China, the heavy burden of study for Chinese high school students is common, and maintaining a healthy lifestyle could be ignored. However, having a healthy lifestyle is one of the most important modifiable factors for students' academic grades. Given the importance of academic grades for high school students, the independent and combined associations between lifestyle behaviours and academic grades targeting this population need to be investigated.

Previous studies have demonstrated that there were some factors related to students' academic grades, lifestyle behaviours or both.[9] [23–28] Faught et al found that girls had a stronger association with the likelihood of meeting expectations for academic achievement in reading and writing than boys, and the area of residence was associated with students' academic achievement in mathematics.[23] Some researchers found that students with higher parental education levels were more likely to obtain better academic achievement.[9] [23] Li's research showed that boarding school students were more likely to obtain better academic grades than those students who did

not board at school.[26] In addition, Pan and Guan found that students' monthly living expenses were negatively correlated with academic performance, also, whether the student was an only child influenced academic performance.[27] These factors were also the possible influencing factors of students' lifestyle behaviours.[23–25] [28] Therefore, the above factors were adjusted as potential confounders in this study.

In the context of metropolitan China, 'urban' refers to inner urban and peri-urban areas. Peri-urbanisation refers to the dispersal of urban growth towards the rural surroundings of cities (urban sprawl), thereby creating landscapes that are characterised by urban and rural social and economic activities.[29] Inner urban districts have higher socioeconomic levels than peri-urban districts in Chongqing, China.[30] The lifestyle of students differs across various socioeconomic school levels[31] and is likely to have different influences on the students' academic grades.

To the best of our knowledge, limited studies have investigated the combined associations between lifestyle behaviours and students' academic grades. Hence, this study aims to (1) explore the individual associations between multiple lifestyle behaviours (physical activity before or after school or on weekends, physical activity at school, sleep duration on weekdays and weekends, screen time on weekdays and weekends, consumption frequency of sugar-sweetened beverages (SSBs), breakfast, lunch, dinner, vegetables, fruit, milk and milk alternatives, and the quantity of water and egg consumption) and academic grades among inner urban high school students (IUHSSs) and peri-urban high school students (PUHSSs) in grades 10 and 11 in Chongqing, China, and (2) explore the combined associations between multiple lifestyle behaviours and academic grades in IUHSSs and PUHSSs. This study is expected to effectively promote multiple healthy lifestyle behaviours among high school students from areas with different economic levels and obtain a better understanding of the independent and combined associations between multiple lifestyle behaviours and academic grades of high school students.

METHODS
Study design and study sample
A cross-sectional survey was conducted in Chongqing among 1481 high school students. Chongqing is a municipality in midwestern China with 26 districts, including nine inner urban districts and 17 peri-urban districts. One inner urban (Jiangbei) and two peri-urban districts (Dazu and Kaizhou) were randomly chosen in Chongqing, and one high school was randomly selected from each designated district. A total of 6–12 classes were randomly selected from each school, and all students in the selected classes were invited to participate in this study. High school students in grades 10 and 11 were eligible to participate in this study. Students who have a history of major diseases, chronic health conditions or

mental trauma were excluded in this study. Investigators explained the research and distributed the questionnaire to all students, and students promptly completed the anonymous questionnaire independently.

According to the research of Yan *et al*[32], nearly 48% of middle-school and high-school students reported having good grade rankings in their final examination. According to the sample size calculation formula of the cross-sectional study $N = \left(Z_\alpha^2 \times p \times q\right)/d^2$, we set p = 0.48, q = 1 - p = 0.52, and margin of error d = 0.10 × p=0.048, Z_α = 1.96, the calculated sample size was 416. In the survey, the actual total sample size included 1481 individuals.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Exposure

The descriptions of 15 questions in terms of lifestyle behaviours (physical activity, sleep duration, screen time and dietary behaviours) are presented in online supplemental table 1. Healthy lifestyle behaviours were assessed based on the recommended guidelines or previous studies. High school students who engage in moderate-to-high-intensity physical activity for more than 1 hour a day and whose screen time is less than 2 hours a day meet the physical activity guidelines for Chinese children and adolescents.[33] Physical activity was categorised into ≥1 hour and <1 hour, and daily screen time was categorised into ≥2 hours and <2 hours. Insufficient sleep was defined as less than 8 hours a day for high school students, as recommended by the Chinese Dietary Guideline 2016.[34] Sleep duration was categorised into ≥8 hours and <8 hours. In terms of dietary behaviours, participants were asked about the consumption frequency of SSBs, breakfast, lunch, dinner, vegetables, fruit, milk and milk alternatives, and the quantity of water and egg consumption. As recommended by the Chinese Dietary Guideline 2016,[34] water and egg consumption were divided into two categories, namely, meeting the guideline and not meeting the guideline. Consumption of SSBs less than once a week, consumption of breakfast, lunch and dinner five or more times per week, and consumption of vegetables, fruit, and milk and milk alternatives more than once per day were considered as healthy dietary behaviours.[35–37]

Outcome

Academic grades were approximately assessed based on the students' self-reported ranking in the last cumulative examination in their grades, with the options being the top 25%, 25%–50%, 50%–75% and lowest 25%. With reference to previous studies,[4 32] academic grades were dichotomised into good (top 50%) and poor (last 50%) for statistical analyses.

Potential confounders

Analyses were adjusted in terms of school areas, age, gender (male/female), residence (urban/rural), being an only child in the family (yes/no), boarding school (yes/no), average monthly living expenses (low: ≤RMB800, medium: RMB801–RMB1200 and high: >RMB1200), and parental education level (low: primary school or below, medium: secondary school/secondary vocational school/high school and high: college or above).

Statistical analyses

All analyses were performed with the Statistical Package for Social Sciences (SPSS) software V.21 (IBM). Invalid or missing data were excluded, and all data were double-checked. The categorical variables were described using frequency and percentiles, and owing to the non-normal distribution of age, we described age using median and IQR. χ^2 tests were conducted to examine the differences in lifestyle behaviours between IUHSSs and PUHSSs. The independent and combined associations between multiple lifestyle behaviours and academic grades were assessed through multivariate logistic regressions. ORs and their corresponding 95% CIs were reported. An unadjusted logistic regression was used to assess the independent associations between multiple lifestyle behaviours and academic grades in all students, IUHSSs and PUHSSs, respectively. In all students, the adjusted model reported the results of multivariate regression analysis after adjusting the potential confounders (school area, age, gender, residence, being an only child, boarding at the school, average monthly living expenses, and parental education level) and all lifestyle behaviours. In IUHSSs and PUHSSs, the adjusted model reported the results of multivariate regression analysis after adjusting age, gender, residence, being an only child, boarding at the school, average monthly living expenses, and parental education level and all lifestyle behaviours, respectively. The effect of the number of healthy lifestyle behaviours was considered to assess the combined associations between multiple lifestyle behaviours and academic grades. The total number of healthy lifestyle behaviours ranged from 1 to 13, and three categories of healthy lifestyle behaviours were constructed in accordance with the frequency distribution of the number of healthy lifestyle behaviours: low (1–6 healthy lifestyle behaviours, 40.0%), medium (7–8 healthy lifestyle behaviours, 38.8%) and high (9–13 healthy lifestyle behaviours, 21.2%). Treating the number of healthy lifestyle behaviours as both categorical and continuous variables, univariable and multivariable regression models were used to assess the cumulative associations between multiple lifestyle behaviours and academic grades. A p<0.05 (two-sided) was considered as statistical significance.

RESULTS

Sample characteristics

Table 1 shows the sample characteristics of participants. IUHSSs comprised 45.8% out of 1481 high school

Table 1 Demographic characteristics of participants (n=1481)

Variables		n (%) or mean±SD
School areas	Inner urban	678 (45.8)
	Peri-urban	803 (54.2)
Age (median (IQR))		16.0 (1.0)
Gender	Boy	739 (49.9)
	Girl	742 (50.1)
Residence	City	957 (64.6)
	Village	524 (35.4)
Only-child status	Yes	525 (35.5)
	No	956 (64.5)
Boarding school	Yes	859 (58.0)
	No	622 (42.0)
Average monthly living expenses (RMB)	Low	861 (58.1)
	Medium	465 (31.4)
	High	155 (10.5)
Father's educational level	Low	163 (11.0)
	Medium	832 (56.2)
	High	486 (32.8)
Mother's educational level	Low	278 (18.8)
	Medium	808 (54.6)
	High	395 (26.6)
Academic grades	Top 50%	945 (63.8)
	Last 50%	536 (36.2)

students (49.9% boys). The median age is 16.0. Among the students, 64.6% lived in the city, 64.5% had siblings and 58.0% were boarding school. More than half (58.1%) of the students' average monthly living expenses were less than RMB800. More than half of the parental education level were medium (56.2% and 54.6%, respectively). And 63.8% of the students' academic grades were ranked as top 50%.

Lifestyle behaviours of participants
Table 2 shows the comparison of lifestyle behaviours between IUHSSs and PUHSSs. The percentages of students meeting the recommendations of lifestyle behaviours were: 5.6% and 19.5% for daily physical activity before or after school or on weekends and at school, respectively; 10.8% and 70.5% for daily sleep duration on weekdays and on weekends, respectively; 81.4% and 18.4% for daily screen time on weekdays and on weekends, respectively; and 18.5% and 23.0% for water and egg consumption, respectively. And 27.3% of the students drank SSBs less than once a week. Breakfast, lunch and dinner consumption five times or more per week were 83.8%, 96.2% and 79.1%, respectively. Vegetable, fruit, and milk and milk alternatives consumption more than once per day were 79.1%, 42.4% and 42.7%, respectively.

All lifestyle behaviours varied between IUHSSs and PUHSSs except for physical activity at school, frequency of breakfast, dinner and vegetable intake, and water and egg consumption (p<0.05).

Logistic regression for identifying the independent and combined associations of multiple lifestyle behaviours and academic grades among IUHSSs and PUHSSs
The results of the logistic regression analysis for identifying the independent associations between multiple lifestyle behaviours and academic grades are shown in table 3.

In the adjusted model, among all students, students who met the recommendations for sleep duration on weekends (OR 1.39, 95% CI 1.10 to 1.77) and eating dinner regularly (≥5 times/week vs <5 times/week: OR 1.47, 95% CI 1.11 to 1.95) were significantly correlated with high academic grades; students with high frequency of SSBs consumption (≥5 times/week vs <once/week: OR 0.66, 95% CI 0.48 to 0.92) were unlikely to obtain high academic grades.

In the adjusted model, among IUHSSs, meeting the recommendations for screen time on weekdays (OR 1.57, 95% CI 1.06 to 2.34) and daily egg consumption (OR 1.60, 95% CI 1.04 to 2.47) and high frequency of fruit consumption (≥once/week vs <once/week: OR 1.67, 95% CI 1.11 to 2.50) were still significantly correlated with high academic grades; students who met the recommendations for sleep duration on weekdays (OR 0.46, 95% CI 0.21 to 0.98) and high frequency of SSBs consumption (≥5 times/week vs <once/week: OR 0.56, 95% CI 0.32 to 0.99) were unlikely to obtain high academic grades. Among PUHSSs, meeting the recommendations for sleep duration on weekends (OR 1.40, 95% CI 1.02 to 1.93) and eating dinner regularly (≥5 times/week vs <5 times/week: OR 1.55, 95% CI 1.01 to 2.37) were significantly correlated with high academic grades; students with high frequency of SSBs consumption (3–4 times/week vs <once/week: OR 0.63, 95% CI 0.42 to 0.96) were unlikely to obtain high academic grades.

The results of the logistic regression analysis for identifying the combined associations between multiple lifestyle behaviours and academic grades are shown in table 4. In the adjusted model, the number of healthy lifestyle behaviours in all students was positively associated with academic grades (OR 1.12, 95% CI 1.05 to 1.19), and students who had 9–13 healthy lifestyle behaviours were more likely to obtain high academic grades than those who had 1–6 healthy lifestyle behaviours (OR 1.74, 95% CI 1.28 to 2.37).

In the adjusted model, the number of healthy lifestyle behaviours among IUHSSs was positively associated with academic grades (OR 1.23, 95% CI 1.11 to 1.35). And IUHSSs who had 7–8 healthy lifestyle behaviours were more likely to obtain high academic grades than those who had 1–6 healthy lifestyle behaviours (OR 1.54, 95% CI 1.06 to 2.24), IUHSSs who had 9–13 healthy lifestyle behaviours had 3.25 times higher odds of obtaining high

Table 2 The comparison of lifestyles behaviours of students between inner urban and peri-urban high schools in Chongqing, China (n=1481)

Variables	Total population	Inner urban (n=678)	Peri-urban (n=803)	χ^2	P value
Physical activity before or after school or on weekends					
<1 hour	1398 (94.4)	631 (93.1)	767 (95.5)	4.17	0.04
≥1 hour	83 (5.6)	47 (6.9)	36 (4.5)		
Physical activity at school					
<1 hour	1192 (80.5)	547 (80.7)	645 (80.3)	0.03	0.86
≥1 hour	289 (19.5)	131 (19.3)	158 (19.7)		
Sleep time on weekdays					
<8 hours	1321 (89.2)	643 (94.8)	678 (84.4)	41.30	<0.001
≥8 hours	160 (10.8)	35 (5.2)	125 (15.6)		
Sleep time on weekends					
<8 hours	437 (29.5)	171 (25.2)	266 (33.1)	11.04	<0.001
≥8 hours	1044 (70.5)	507 (74.8)	537 (66.9)		
Screen time on weekdays					
≥2 hours	276 (18.6)	157 (23.2)	119 (14.8)	16.85	<0.001
<2 hours	1205 (81.4)	521 (76.8)	684 (85.2)		
Screen time on weekends					
≥2 hours	1208 (81.6)	581 (85.7)	627 (78.1)	14.16	<0.001
<2 hours	273 (18.4)	97 (14.3)	176 (21.9)		
Sugar-sweetened beverages					
≥5 times/week	343 (23.2)	174 (25.7)	169 (21.1)	51.30	<0.001
3–4 times/week	333 (22.5)	169 (24.9)	164 (20.4)		
1–2 times/week	401 (27.1)	211 (31.1)	190 (23.6)		
<Once/week	404 (27.3)	124 (18.3)	280 (34.9)		
Breakfast					
<5 times/week	240 (16.2)	110 (16.2)	130 (16.2)	0.00	0.99
≥5 times/week	1241 (83.8)	568 (83.8)	673 (83.8)		
Lunch					
<5 times/week	56 (3.8)	14 (2.1)	42 (5.2)	10.12	0.001
≥5 times/week	1425 (96.2)	664 (97.9)	761 (94.8)		
Dinner					
<5 times/week	309 (20.9)	155 (22.9)	154 (19.2)	3.02	0.08
≥5 times/week	1172 (79.1)	523 (77.1)	649 (80.8)		
Vegetables					
<Once/day	310 (20.9)	156 (23.0)	154 (19.2)	3.26	0.07
≥Once/day	1171 (79.1)	522 (77.0)	649 (80.8)		
Fruit					
<Once/day	853 (57.6)	349 (51.5)	504 (62.8)	19.18	<0.001
≥Once/day	628 (42.4)	329 (48.5)	299 (37.2)		
Milk and milk alternatives					
<Once/day	849 (57.3)	290 (42.8)	559 (69.6)	108.26	<0.001
≥Once/day	632 (42.7)	388 (57.2)	244 (30.4)		
Meeting water intake recommendation					
No	1207 (81.5)	544 (80.2)	663 (82.6)	1.32	0.25
Yes	274 (18.5)	134 (19.8)	140 (17.4)		

Continued

Table 2 Continued

Variables	Total population	Inner urban (n=678)	Peri-urban (n=803)	χ^2	P value
Meeting egg intake recommendation					
No	1141 (77.0)	508 (74.9)	633 (78.8)	3.17	0.08
Yes	340 (23.0)	170 (25.1)	170 (21.2)		

academic grades than those who had 1–6 healthy lifestyle behaviours (OR 3.25, 95% CI 1.96 to 5.40). No combined association was found between lifestyle behaviours and academic grades among PUHSSs (p>0.05).

DISCUSSION

Lifestyle behaviours of high school students appear to be associated with academic grades, and the cumulative associations between multiple healthy lifestyle behaviours and their academic outcomes seem to be stronger than the independent associations. These findings are particularly applicable to IUHSSs. Lifestyle behaviours are closely related to education, the findings in this study revealed that multiple healthy lifestyle behaviours of high school students may be positively associated with their academic achievement.

Previous studies reported that meeting the recommendation of sleep duration was positively associated with the academic grades of children and adolescents.[14 15] Sleep is thought to play a crucial and specific role in memory consolidation, and lack of sleep was linked to increased fatigue and sleepiness, and poor attention and cognition.[38 39] However, the association between sleep duration and academic grades among IUHSSs and PUHSSs was inconsistent in this study. Among PUHSSs, meeting the recommendation for sleep duration on weekends had a positive association with students' academic grades. By contrast, a negative association was found between adhering to the recommended sleep duration on weekdays and academic grades among IUHSSs. Education development is usually synchronized with economic development, and regional differences in education development in Chongqing were found.[40] Inner urban high schools may have stricter rules and tighter schedules compared with peri-urban high schools, and insufficient sleep may be common among IUHSSs. The result of this study showed that extremely few IUHSSs (5.2%) had 8 hours or more sleep duration on weekdays. We speculated that IUHSSs who slept 8 hours or more on weekdays may sleep at other times, such as during class or independent study time, leading to less time spent studying. In addition, IUHSSs with good academic grades may spend more time in learning than those with poor academic grades, which could be another possible explanation for the negative association between insufficient sleep time on weekdays and good academic grades among IUHSSs.

A previous systematic review and meta-analysis indicated that television viewing and video game playing were negatively associated with academic outcomes, while overall screen time (including watching television, playing electronic games, receiving electronic news and study materials, and using social networking sites) was not associated with academic outcomes among children and adolescents aged 4–18 years.[16] The screen time surveyed in this study was overall screen time. The results revealed that meeting the recommendation for screen time on weekdays had a positive association with academic grades, and the association between weekend screen time and academic performance was statistically insignificant among IUHSSs. One possible explanation could be that Chinese high school students are not allowed to use electronic devices on weekdays owing to the strict regulations, but they may use electronic devices in 'cram schools' on weekends for receiving electronic news and study materials that may neutralise the negative association between screen-based behaviours and academic grades. No association between screen time and academic grades was found among PUHSSs. The reason could be that students from inner urban areas may have greater access to screen devices and would be more likely to engage in screen-based behaviours compared with those from peri-urban high schools.

The results in this study showed increased odds of high academic grades among PUHSSs who had regular dinner consumption, and no association was observed between breakfast, lunch consumption and academic grades. Few studies have explored the relationship between a regular meal pattern throughout the day and academic grades. Many previous studies showed the positive effects of regular breakfast consumption on students' academic grades, and most of them focused on young students.[2 7 41] A study reported that a regular intake of breakfast and lunch was more crucial in grades 5 and 8 students compared with grade 11, whereas a regular intake of dinner was more likely related to academic achievement in grade 11 students compared with grade 5 and grade 8 students.[42] In this study, eating breakfast, lunch and dinner five times or less per week accounted for 16.8%, 3.8% and 20.9%, respectively. The frequency of eating dinner five times or less per week accounted for the highest proportion, possibly because the heavy schoolwork resulting in insufficient time for dinner or skipping dinner was served as a weight control measure among high school students. However, Chinese high school students were required to attend evening classes lasting for several hours,[43] and skipping dinner may affect the learning efficiency of evening classes, which may have an important effect on students' academic grades. This

Table 3 Logistic regression for identifying the independent associations between multiple lifestyle behaviours and academic grades among inner urban and peri-urban high school students in Chongqing, China (n=1481)

Variables	Total population (n=1481)				Inner urban high school students (n=678)				Peri-urban high school students (n=803)			
	Unadjusted		Adjusted*		Unadjusted		Adjusted†		Unadjusted		Adjusted†	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Physical activity before or after school or on weekends												
≥1 hour vs <1 hour	0.77 (0.49 to 1.20)	0.25	0.83 (0.51 to 1.36)	0.46	1.00 (0.53 to 1.88)	0.99	1.50 (0.72 to 3.15)	0.28	0.51 (0.26. 1.01)	0.05	0.57 (0.27 to 1.18)	0.13
Physical activity at school												
≥1 hour vs <1 hour	0.81 (0.62 to 1.06)	0.12	0.84 (0.63 to 1.11)	0.22	0.74 (0.49 to 1.09)	0.13	0.77 (0.48 to 1.23)	0.27	0.88 (0.62 to 1.25)	0.46	0.98 (0.66 to 1.44)	0.91
Sleep duration on weekdays												
≥8 hours vs <8 hours	1.06 (0.75 to 1.49)	0.74	1.01 (0.70 to 1.45)	0.96	**0.47 (0.24 to 0.94)**	**0.03**	**0.46 (0.21 to 0.98)**	**0.04**	**1.56 (1.04 to 2.35)**	**0.03**	1.41 (0.92 to 2.18)	0.12
Sleep duration on weekends												
≥8 hours vs <8 hours	**1.43 (1.14 to 1.80)**	**0.002**	**1.39 (1.10 to 1.77)**	**0.01**	1.35 (0.94 to 1.94)	0.11	1.38 (0.93 to 2.05)	0.11	**1.42 (1.05 to 1.91)**	**0.02**	**1.40 (1.02 to 1.93)**	**0.04**
Screen time on weekdays												
<2 hours vs ≥2 hours	1.21 (0.93 to 1.58)	0.16	1.20 (0.90 to 1.59)	0.21	**1.73 (1.20 to 2.51)**	**0.004**	**1.57 (1.06 to 2.34)**	**0.02**	0.90 (0.61 to 1.35)	0.63	0.89 (0.58 to 1.36)	0.59
Screen time on weekends												
<2 hours vs ≥2 hours	0.89 (0.68 to 1.16)	0.39	0.85 (0.64 to 1.59)	0.21	1.41 (0.87 to 2.29)	0.17	1.15 (0.68 to 1.96)	0.60	0.74 (0.53 to 1.04)	0.09	0.74 (0.51 to 1.08)	0.12
Sugar to sweetened beverages												
≥5 times/week vs <once/week	0.74 (0.55 to 1.00)	0.05	**0.66 (0.48 to 0.92)**	**0.02**	**0.46 (0.28 to 0.77)**	**0.003**	**0.56 (0.32 to 0.99)**	**0.049**	0.93 (0.62 to 1.37)	0.70	0.99 (0.64 to 1.55)	0.98
Three to 4 times/week vs <once/week	0.84 (0.62 to 1.14)	0.27	0.74 (0.54 to 1.02)	0.07	0.88 (0.52 to 1.50)	0.64	1.06 (0.60 to 1.90)	0.83	**0.65 (0.44 to 0.97)**	**0.03**	**0.63 (0.42 to 0.96)**	**0.03**
1–2 times/week vs <once a week	0.81 (0.61 to 1.09)	0.16	0.74 (0.54 to 1.00)	0.05	0.64 (0.39 to 1.06)	0.08	0.78 (0.45 to 1.33)	0.36	0.79 (0.54 to 1.16)	0.23	0.81 (0.54 to 1.21)	0.30
Breakfast												

Continued

Table 3 Continued

Variables	Total population (n=1481)				Inner urban high school students (n=678)				Peri-urban high school students (n=803)			
	Unadjusted OR (95% CI)	P value	Adjusted* OR (95% CI)	P value	Unadjusted OR (95% CI)	P value	Adjusted† OR (95% CI)	P value	Unadjusted OR (95% CI)	P value	Adjusted† OR (95% CI)	P value
≥5 times/week vs <5 times/week	1.27 (0.95 to 1.68)	0.10	1.07 (0.79 to 1.45)	0.65	1.40 (0.92 to 2.14)	0.12	1.08 (0.67 to 1.77)	0.75	1.17 (0.80 to 1.71)	0.41	1.05 (0.70 to 1.59)	0.81
Lunch												
≥5 times/week vs <5 times/week	1.34 (0.78 to 2.30)	0.29	1.00 (0.56 to 1.79)	1.00	0.85 (0.26 to 2.75)	0.79	0.59 (0.17 to 2.08)	0.41	1.40 (0.75 to 2.60)	0.29	1.16 (0.58 to 2.32)	0.68
Dinner												
≥5 times/week vs <5 times/week	**1.42 (1.10 to 1.83)**	**0.01**	**1.47 (1.11 to 1.95)**	**0.01**	**1.49 (1.02 to 2.16)**	**0.04**	1.48 (0.98 to 2.24)	0.06	1.42 (1.00 to 2.02)	0.05	**1.55 (1.01 to 2.37)**	**0.04**
Vegetables												
≥Once a day vs <once a day	0.88 (0.68 to 1.14)	0.34	0.84 (0.63 to 1.12)	0.23	1.09 (0.75 to 1.60)	0.65	0.88 (0.57 to 1.35)	0.56	0.75 (0.52 to 1.08)	0.13	0.74 (0.49 to 1.10)	0.14
Fruit												
≥Once a day vs <once a day	1.17 (0.95 to 1.46)	0.15	1.19 (0.92 to 1.53)	0.19	**1.46 (1.05 to 2.02)**	**0.02**	**1.67 (1.11 to 2.50)**	**0.01**	0.92 (0.69 to 1.23)	0.57	0.94 (0.67 to 1.33)	0.74
Milk and milk alternatives												
≥Once a day vs <once a day	1.31 (1.06 to 1.63)	0.01	1.22 (0.95 to 1.56)	0.12	**1.50 (1.08 to 2.07)**	**0.01**	1.19 (0.82 to 1.74)	0.35	1.01 (0.74 to 1.37)	0.97	1.01 (0.70 to 1.45)	0.97
Meeting water consumption recommendation												
Yes vs no	1.17 (0.89 to 1.55)	0.26	1.20 (0.90 to 1.60)	0.21	1.48 (0.96 to 2.27)	0.07	1.42 (0.90 to 2.26)	0.14	0.96 (0.66 to 1.39)	0.82	1.05 (0.71 to 1.55)	0.82
Meeting egg consumption recommendation												
Yes vs no	1.29 (1.00 to 1.67)	0.05	1.22 (0.93 to 1.61)	0.15	**1.59 (1.07 to 2.35)**	**0.02**	**1.60 (1.04 to 2.47)**	**0.03**	1.06 (0.75 to 1.49)	0.76	1.03 (0.71 to 1.49)	0.87

Results in bold are statistically significant (p<0.05).
*Adjusted for school area, age, gender, residence, only-child status in the family, boarding school, average monthly living expenses, parental education level and all lifestyle behaviours.
†Adjusted for age, gender, residence, only-child status in the family, boarding school, average monthly living expenses, parental education level and all lifestyle behaviours.

Table 4 Logistic regression for identifying the combined associations between multiple lifestyle behaviours and academic grades

Variables	Total population (n=1481)				Inner urban high school students (n=678)				Peri-urban high school students (n=803)			
	Unadjusted		Adjusted*		Unadjusted		Adjusted†		Unadjusted		Adjusted†	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Multiple healthy lifestyle behaviours‡	**1.11 (1.04 to 1.17)**	**0.001**	**1.12 (1.05 to 1.19)**	**<0.001**	**1.22 (1.11 to 1.33)**	**<0.001**	**1.23 (1.11 to 1.35)**	**<0.001**	1.03 (0.96 to 1.11)	0.42	1.03 (0.95 to 1.12)	0.45
Categories of multiple healthy lifestyle behaviours												
Low (1–6)	Ref		Ref		Ref		Ref		Ref		Ref	
Medium (7–8)	1.22 (0.97 to 1.55)	0.09	1.26 (0.99 to 1.61)	0.06	**1.54 (1.08 to 2.21)**	**0.02**	**1.54 (1.06 to 2.24)**	**0.02**	1.02 (0.74 to 1.40)	0.90	1.00 (0.72 to 1.39)	1.00
High (9–13)	**1.60 (1.20 to 2.15)**	**0.002**	**1.74 (1.28 to 2.37)**	**<0.001**	**3.05 (1.88 to 4.95)**	**<0.001**	**3.25 (1.96 to 5.40)**	**<0.001**	1.02 (0.69 to 1.49)	0.94	1.03 (0.68 to 1.54)	0.68

Results in bold are statistically significant (p<0.05).
*Adjusted for school areas, age, gender, residence, only-child status, boarding school, average monthly living expenses, parental education level.
†Adjusted for age, gender, residence, only-child status, boarding school, average monthly living expenses, parental education level.
‡Includes physical activity before or after school or on weekends, physical activity at school, sleep duration on weekdays and weekends, screen time on weekdays and weekends, the consumption frequency of SSBs, breakfast, lunch, dinner, vegetables, fruit, milk and milk alternatives, and the quantity of water and egg consumption.
SSBs, sugar-sweetened beverages.

could be the reason that eating dinner regularly is positively correlated with academic grades. Health education related to regular meal patterns throughout the day must be conducted among high school students, particularly emphasising the importance of eating dinner. In IUHSSs and PUHSSs, high frequency of SSBs consumption was unlikely to obtain high academic grades. Additionally, among IUHSSs, meeting the recommendations for egg consumption and high frequency of fruit consumption had significant associations with high academic grades. These results were largely similar to previous studies,[9 23 44] which demonstrated that healthy dietary behaviours, such as frequent fruit consumption, were associated with high academic performance, whereas unhealthy dietary behaviours, including high frequency of SSBs consumption, were associated with poor academic performance.

In this study, no association was found between physical activity before or after school or on weekends, physical activity at school and academic grades in IUHSSs and PUHSSs. Most laboratory trials, cohort-based or cross-sectional studies have demonstrated the positive effect of physical activity on cognitive function,[45–48] while, studies on physical activity and academic grades have produced mixed results.[49 50] A previous study found an inverse U-shaped curvilinear association between physical activity and academic achievement, thereby indicating that too little physical activity might impair the positive effects of physical activity on students' cognitive function and top sports students may have additional extracurricular physical activity that displaced the time spent on academics.[51] Moreover, under the social, cultural and educational background of China, many schools have reduced the physical education curriculum to maximise the study time on important subjects for exams.[18] This phenomenon is particularly prominent in high schools, as high school students need to prepare for the National College Entrance Examination.[1] The results of this study showed that only 5.6% of the students before or after school or on weekends, and 19.5% of the students at school have more than 1 hour of physical activity. Considering these factors, the cut-off values of the recommendation for physical activity may be inappropriate to assess the association between physical activity and academic grades of high school students, and this could be the reason for the lack of significant association between physical activity and academic grades in IUHSSs and PUHSSs. This was also mentioned in a previous study targeting the association between physical activity and academic achievement among elementary school students.[23] In addition, the questionnaire used for assessing the level of physical activity was not evaluated for its reliability and validity, the limited information provided by the questionnaire could be another reason for the lack of association. Choosing the appropriate method to assess the physical activity of high school students still needs to be explored in future studies, thereby to better explore its association with academic performance.

The findings demonstrated that the combined associations of multiple lifestyle behaviours resulted in a

substantially higher likelihood of obtaining academic grades than the independent associations among IUHSSs, which was similar to the results of previous studies that investigated the combined effects of meeting recommendations for diet, physical activity, screen time and sleep on academic achievement of primary school students.[22 23] Overall, one possible explanation for the positive association between multiple lifestyle behaviours and academic grades is that high school students with good academic grades usually have better self-control, which could contribute to high adherence to a healthy lifestyle. This study complements and extends these important findings in high school students. Given the importance of academic grades for high school students, this study could provide valuable references for health promotion initiatives that lead to improvement in academic grades. Interventions aiming to improve multiple lifestyle behaviours may have a greater positive effect on the academic grades of high school students than those focusing on a single lifestyle behaviour.

Regarding the potential mechanisms on the associations between lifestyle behaviours and academic grades, a previous study showed that adolescence is a critical period in which there is considerable reorganisation and growth of many brain structures, including the hippocampus related to learning and memory.[52] Increasingly evidence demonstrates that the hippocampus is particularly responsive to the lifestyle influences during adolescence, previous studies showed that unhealthy diet and decreased exercise levels have been associated with decreased hippocampal neurogenesis and cognitive performance in rodent models.[53–55] And the brain-derived neurotrophic factor system appears to be a major mechanism underlying the effects of exercise and diet on neurogenesis and cognitive function.[52 56]

This study has certain limitations. First, the use of cross-sectional survey data reduces the researchers' ability to make direct causal inferences. Future longitudinal studies should be conducted to confirm the findings of this study. Second, lifestyle behaviours and academic grades were obtained by self-report that may introduce bias caused by self-enhancement and measurement flaws. Third, academic grades in this study is a comprehensive ranking of all compulsory subjects, however, students' lifestyle behaviours could have different influences on different subjects,[23] the independent and combined associations between multiple lifestyle behaviours and academic grades among Chinese high school students could be explored in further studies according to the classification of students (science or liberal students), as well as the classification of subjects (Chinese, English, mathematics, physics, chemistry, biology, geography, history or politics). Fourth, being an exploratory study, questions on physical activity, sleep duration and screen time were adapted from the China Health and Nutrition Survey,[57] and questions on dietary behaviours were adapted from Chinese Dietary Guideline 2016.[34] Additionally, expert review and a pilot study were done before implementation. However,

the questionnaire was not evaluated for its reliability and validity, and the unvalidated measures in the questionnaire designed to measure the lifestyle behaviours and academic grades may raise potential issues related to reliability. Further studies should consider using a verified questionnaire or validating the questionnaire before administration. Fifth, the participants who were investigated in this study could only reflect the situation of high school students in Chongqing to a certain extent, and cannot be generalisable to all high school students across China. Further nationally representative studies are warranted.

CONCLUSIONS

This study demonstrated that there is a correlation between the lifestyle behaviours of high school students and academic grades, and cumulative associations between multiple healthy lifestyle behaviours and academic grades appear to be stronger than the independent associations. These findings are particularly applicable to IUHSSs. The importance of multiple healthy lifestyle behaviours for the academic grades of high school students should be considered by public health decision-makers and school principals or management bodies in the high school settings.

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obtained from all participants, and they could voluntarily participate or withdraw from the study at any stage.

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