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Independent and Combined Effects of Lifestyle Behaviors on Academic Grades of Inner Urban and Peri-Urban High School Students: A Cross-Sectional Study in Chongqing, China

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Abstract

Objectives Limited studies reported the associations between multiple lifestyle factors and academic grades. This study aims to assess the independent and combined effects of multiple lifestyle behaviors on academic grades of inner urban high school students (IUHSSs) and peri-urban high school students (PUHSSs).

Design A cross- sectional study.

Participants 1,481 high school students (49.9% boys) were included, who were enrolled from one inner urban and two peri-urban districts in Chongqing, China.

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

Results: In IUHSSs and PUHSSs, high frequency of sugar-sweetened beverage consumption was unlikely to obtain high academic grades (OR, 0.56 [95% CI 0.32–0.99] and 0.63 [0.41–0.95], respectively). Among IUHSSs, meeting the recommendations for weekdays' screen time and egg consumption (1.57 [1.06–2.34] and 1.60 [1.04–2.47], respectively), and high frequency of fruit consumption (1.67 [1.11–2.50]) were significantly associated with high academic grades; meeting the recommendation for weekdays' sleep duration was unlikely to obtain high academic grades (0.46 [0.21–0.98]). Among PUHSSs, meeting the recommendations for weekends' sleep duration (1.40 [1.02–1.93]) and regularly eating dinner (1.55 [1.01–2.37]) had significant association with high academic grades. No significant differences were found between physical activity and academic grades in IUHSSs and PUHSSs ($p > 0.05$). Moreover, IUHSSs with 9–13 healthy lifestyle behaviors were 3.25 times more likely to achieve high academic grades than IUHSSs with six or less healthy lifestyle behaviors (3.25 [1.96–5.40]). No significant differences were

found in the combined effects of multiple lifestyle behaviors on the academic grades among PUHSSs ($p > 0.05$).

Conclusions: Correlations were observed between lifestyle behaviors of high school students and academic grades, and cumulative effects of healthy lifestyle behaviors have a stronger association with academic outcomes than the independent effects. These findings are particularly applicable to IUHSSs.

Keywords: Lifestyle behaviors, Physical activity, Sleep duration, Screen time, Dietary behaviors, Academic grades, High school students, School health

Strengths and limitations of this study

- We provide the evidence of relationship between such a wide range of health behaviors and academic grades in high school students.
- Study participants represent inner urban and peri-urban population, results in this study could be generalizable to other settings with economic disparities.
- All the data were self-reported.
- The cross-sectional design in this study does not allow for causal inference.

INTRODUCTION

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

Healthy dietary behaviors, sufficient physical activity and sleep, and minimal screen time contribute to a healthy lifestyle that might be associated with students' high academic performance.[2, 3] Studies examining the associations between dietary behaviors and academic achievement have typically focused on micronutrient intake,[4] dietary intake,[5] and breakfast consumption.[2, 6] Certain micronutrients (such as iron), high frequency of fruit and vegetable consumption, low consumption of energy-dense and nutrient-poor food, and regular breakfast consumption might be associated with high academic grades.[4, 6-8] Current studies on the association between physical activity and academic grades of children and adolescents are inconsistent. With reported evidence of exercise affecting cognition,[9] the positive influence of appropriate physical activities on the academic grades of children and adolescents is observed.[10, 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 of poor sleep quality with 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 watching television, videos, and social networking sites may be negatively associated with academic grades.[16, 17]

Previous studies mainly explored the association between a single lifestyle factor and the

academic grades of students.[2, 3, 16, 18] However, some scholars have proposed that the relationship between healthy lifestyle behaviors and academic performance is not isolated, and the combined effects of multiple healthy lifestyle behaviors on academic performance may be greater than any behavior alone.[19-21] To the best of our knowledge, limited studies have investigated the effect of combined associations of multiple lifestyle behaviors on students' academic grades.[22, 23] Ickovics et al. found that children in grades 5-6 with high levels of "health assets" including indicators of healthy diet, physical activity, screen time, and sleep, are two times higher to meet the goal of standardized exams.[22] Faught et al. found that grade 5 students who met the recommendations for 7–9 lifestyle behaviors have higher odds of meeting the expectations for academic achievement compared with those who met three or less recommendations.[23] Given the importance of academic grades for high school students, the independent and combined effects of lifestyle behaviors on the academic grades targeted this population need to be investigated.

In the context of metropolitan China, "urban" refers to inner urban and peri-urban areas. Peri-urbanization refers to the dispersal of urban growth toward the rural surroundings of cities (urban sprawl), thereby creating landscapes that are characterized by urban and rural social and economic activities.[24] Inner urban districts have higher socioeconomic levels than peri-urban districts in China. The lifestyle of students may differ across various socioeconomic school levels[25] and may have different influences on the students' academic grades. Hence, this study aims to (1) explore the individual effects of lifestyle behaviors (physical activity before or after school, 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) on the 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 effects of lifestyle behaviors on the academic grades in IUHSSs and PUHSSs. This study is expected to effectively promote multiple healthy lifestyle behaviors among high school students from areas with different economic levels and obtain a better understanding of the independent and combined effects of multiple lifestyle behaviors on the 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 and two peri-urban districts, namely, Jiangbei, Dazu, and Kaixian Districts, were randomly chosen in Chongqing, and one high school was selected from each designated district. Six to twelve classes were randomly selected in 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. The exclusion criteria were students who have a history of major diseases, chronic health conditions, or mental trauma. Investigators explained the research and distributed the questionnaire to all students, and they promptly completed the anonymous questionnaire independently.

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 fifteen questions in terms of lifestyle behaviors (physical activity, sleep duration, screen time, and dietary behaviors) are presented in Supplementary Table 1. Healthy lifestyle behaviors 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 h a day and whose screen time is less than 2 h a day meet the physical activity guidelines for Chinese children and adolescents.[26] Average daily physical activity was categorized into ≥1 h and <1 h, and daily screen time was categorized into ≥2 h and <2 h. Insufficient sleep was defined as less than 8 h a day for high school students, as recommended by the Chinese Dietary Guideline 2016.[27] Sleep duration was categorized into ≥8 h and <8 h. In terms of dietary behaviors, 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,[27] 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 behaviors.[28-30]

Outcome

Academic grades were approximately assessed based on the students' self-reports of grade ranking on the last cumulative examination in their grade, with the options being the top 25%, 25–50%, 50–75% and lowest 25%. Answer selections were divided into two categories for analysis, namely, good (top 50%) and poor (last 50%) academic grades.

Potential confounders

Analyses were adjusted in terms of age, gender (male/female), residence (urban/rural), being an only child in the family (yes/no), boarding at school (yes/no), average monthly living expenses (low: ≤800 RMB, medium: 801–1200 RMB, and high: >1200 RMB), and parents' educational 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 version 21 (IBM Corporation, Chicago, IL, USA). Invalid or missing data were excluded, and all data were double-checked. The categorical variables were described using frequency and percentiles, and the continuous variables were described as mean and standard deviation. Chi-square test were conducted to examine the differences in lifestyle behaviors between IUHSSs and PUHSSs. The independent and combined effects of multiple lifestyle behaviors on academic grades were assessed through multivariate logistic regressions. Odds ratios (ORs) and their corresponding 95% confidence intervals (95% CI) were reported. An unadjusted logistic regression was used to assess the independent effects of each lifestyle behavior on the academic grades among IUHSSs and PUHSSs. Model 1 reported the results of multivariate regression analysis after adjusting the potential confounders (age, gender, residence, being an only child, boarding at the school, average monthly living expenses, and parents' educational level) and all lifestyle behaviors. The effect of the number of healthy lifestyle behaviors was considered to assess combined effects of multiple lifestyle behaviors on academic grades. The number of healthy lifestyle behaviors was constructed, and the total number of healthy lifestyle behaviors

ranged from 0 to 13. The healthy lifestyle behaviors of students were divided into three categories in accordance with the frequency distribution of the number of healthy lifestyle behaviors: low (≤6 healthy lifestyle behaviors, 40.0%), medium (7–8 healthy lifestyle behaviors, 38.8%), and high (9–13 healthy lifestyle behaviors, 21.2%). Treating the number of healthy lifestyle behaviors as both categorical and continuous variables, univariable and multivariable regression models were used to assess the cumulative effects of lifestyle behaviors on academic grades. $p < 0.05$ (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 students (mean 16.3 years, 49.9% boys). Among the students, 64.6% lived in the city, 64.5% had siblings, and 58.0% were boarding at school. More than half (58.1%) of the students' average monthly living expenses were less than 800 RMB. More than half of parental educational level of the students were medium (56.2% and 54.6%, respectively). And 63.8% of the students' academic grades were ranked as top 50% in their grade.

Table 1 Demographic characteristics of participants (n = 1481)

Variables		n (%) or Mean ± SD
School areas	Inner urban	668 (45.8)
	Peri-urban	803 (54.2)
Age		16.3 ± 0.9
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 at 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)

Lifestyle behaviors of participants

Table 2 shows the comparison of lifestyle behaviors between IUHSSs and PUHSSs. The percentages of students meeting the recommendations of lifestyle behaviors were: 5.6% and 19.5% for daily physical activity before or after school 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 behaviors varied between IUHSSs and PUHSSs except for physical activity at school, frequency of breakfast, dinner and vegetable intake, and water and egg consumption ($p < 0.05$).

Table 2 The comparison of lifestyles behaviors 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
Physical activity before or after school					
<1 h	1,398 (94.4)	631 (93.1)	767 (95.5)	4.17	0.04
≥1 h	83 (5.6)	47 (6.9)	36 (4.5)		
Physical activity at school					
<1 h	1,192 (80.5)	547 (80.7)	645 (80.3)	0.03	0.86
≥1 h	289 (19.5)	131 (19.3)	158 (19.7)		
Weekdays sleep time					
<8 h	1,321 (89.2)	643 (94.8)	678 (84.4)	41.30	<0.000
≥8 h	160 (10.8)	35 (5.2)	125 (15.6)		
Weekends sleep time					
<8 h	437 (29.5)	171 (25.2)	266 (33.1)	11.04	<0.000

≥8 h	1044 (70.5)	507 (74.8)	537 (66.9)		
Weekdays screen time					
≥2 h	276 (18.6)	157 (23.2)	119 (14.8)	16.85	<0.000
<2 h	1,205 (81.4)	521 (76.8)	684 (85.2)		
Weekends screen time					
≥2 h	1,208 (81.6)	581 (85.7)	627 (78.1)	14.16	<0.000
<2 h	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	1,241 (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	1,425 (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	1,172 (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	1,171 (79.1)	522 (77.0)	649 (80.8)		
Fruit					
<once/day	853 (57.6)	349 (51.5)	504 (62.8)	19.18	<0.000
≥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	<0.000
≥once/day	632 (42.7)	388 (57.2)	244 (30.4)		
Meeting water intake recommendation					
No	1,207 (81.5)	544 (80.2)	663 (82.6)	1.32	0.25
Yes	274 (18.5)	134 (19.8)	140 (17.4)		
Meeting egg intake recommendation					
No	1,141 (77.0)	508 (74.9)	633 (78.8)	3.17	0.08
Yes	340 (23.0)	170 (25.1)	170 (21.2)		

Logistic regression for identifying the independent association of lifestyle behaviors with academic grades among IUHSSs and PUHSSs

The results of the logistic regression analysis for identifying the independent effects of multiple lifestyle behaviors on academic grades are shown in Table 3. In the unadjusted model, among IUHSSs, meeting the recommendations for screen time on weekdays (OR = 1.73, 95% CI [1.20–2.51]) and daily egg consumption (OR = 1.59, 95% CI [1.07–2.35]), regularly eating dinner (≥5 times/week vs. <5 times/week: OR = 1.49, 95% CI [1.02–2.16]), high frequency of fruit consumption (≥once/week vs. <once/week: OR = 1.46, 95% CI [1.05–2.02]), and high frequency

of milk and milk alternatives consumption (≥once/week vs. <once/week: OR = 1.50, 95% CI [1.08–2.07]) had significant univariate associations with high academic grades; students who met the recommendations for sleep duration on weekday (OR = 0.47, 95% CI [0.24–0.94]) and high frequency of SSBs consumption (≥5 times/week vs. <once/week: OR = 0.46, 95% CI [0.28–0.77]) were unlikely to obtain high academic grades. Among PUHSSs, meeting the recommendations for daily screen duration on weekdays and on weekends (OR = 1.56, 95% CI [1.04–2.35] and OR = 1.42, 95% CI [1.05–1.91], respectively) had significant univariate associations with high academic grades; students with high frequency of SSBs consumption (3–4 times/week vs. <once/week: OR = 0.65, 95% CI [0.44–0.97]) were unlikely to obtain high academic grades.

In the Model 1, after adjusting the potential confounders (age, gender, residence, being an only child in the family, boarding at school, average monthly living expenses, and parents' educational level) and all lifestyle behaviors, among IUHSSs, meeting the recommendations for screen time on weekdays (OR = 1.57, 95% CI [1.06–2.34]) and daily egg consumption (OR = 1.60, 95% CI [1.04–2.47]), and high frequency of fruit consumption (≥once/week vs. <once/week: OR = 1.67, 95% CI [1.11–2.50]) were still significantly correlated with high academic grades; students who met the recommendations for sleep duration on weekdays (OR = 0.46, 95% CI [0.21–0.98]) and high frequency of SSBs consumption (≥ 5 times/week vs. <once/week: OR = 0.56, 95% CI [0.32–0.99]) were still unlikely to obtain high academic grades. Among PUHSSs, meeting the recommendations for sleep duration on weekends (OR = 1.40, 95% CI [1.02–1.93]) and regularly eating dinner (≥ 5 times/week vs. <5 times/week: OR = 1.55, 95% CI [1.01–2.37]) 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 [0.41–0.95]) were still unlikely

to obtain high academic grades.

The results of the logistic regression analysis for identifying the combined effects of multiple lifestyle behaviors on academic grades are shown in Table 4. In the unadjusted model, the number of healthy lifestyle behaviors was considered as a continuous variable, the number of healthy lifestyle behaviors was positive associated with academic grades among IUHSSs (OR = 1.22, 95% CI [1.11–1.33]). And the number of healthy lifestyle behaviors was also considered as a categorical variable. IUHSSs who had seven to eight healthy lifestyle behaviors were more likely to obtain high academic grades than those who had six or less healthy lifestyle behaviors (OR = 1.54, 95% CI [1.08–2.21]), and IUHSSs who had 9–13 healthy lifestyle behaviors had 3.05 times higher odds of obtaining high academic grades than those who had six or less healthy lifestyle behaviors (OR = 3.05, 95% CI [1.88–4.95]). No differences were found between the number of healthy lifestyle behaviors and academic grades among PUHSSs (P > 0.05).

In Model 1, after adjusting for the possible confounders, the number of healthy lifestyle behaviors among IUHSSs was positive associated with academic grades (OR = 1.23, 95% CI [1.11–1.35]). And IUHSSs who had seven to eight healthy lifestyle behaviors were more likely to obtain high academic grades than those who had six or less healthy lifestyle behaviors (OR = 1.54, 95% CI [1.06–2.24]), IUHSSs who had 9–13 healthy lifestyle behaviors had 3.25 times higher odds of obtaining high academic grades than those who had six or less healthy lifestyle behaviors (OR = 3.25, 95% CI [1.96–5.40]). No differences were still found between the number of healthy lifestyle behaviors and academic grades among PUHSSs ($p > 0.05$).

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

Variables	Inner urban high school students				Peri-urban high school students			
	Unadjusted		Model 1 [a]		Unadjusted		Model 1 [a]	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Physical activity before or after school								
≥1 h vs. <1 h	1.00 (0.53-1.88]	0.99	1.50 (0.72-3.15)	0.28	0.51 (0.26. 1.01)	0.05	0.57 (0.27-1.18)	0.13
Physical activity at school								
≥1 h vs. <1 h	0.74 (0.49- 1.09)	0.13	0.77 (0.48-1.23)	0.272	0.88 (0.62-1.25)	0.46	0.98 (0.66-1.44)	0.91
Sleep duration on weekdays								
≥8h vs. <8h	**0.47 (0.24-0.94)**	**0.03**	**0.46 (0.21-0.98)**	**0.04**	**1.56 (1.04-2.35)**	**0.03**	1.41 (0.92-2.18)	0.12
Sleep duration on weekends								
≥8h vs. <8h	1.35 (0.94-1.94)	0.11	1.38 (0.93-2.05)	0.11	**1.42 (1.05-1.91)**	**0.02**	**1.40 (1.02-1.93)**	**0.04**

Screen time on weekdays								
<2h vs. ≥2h	**1.73 (1.20-2.51)**	**0.004**	**1.57 (1.06-2.34)**	**0.02**	0.90 (0.61-1.35)	0.63	0.89 (0.58-1.36)	0.59
Screen time on weekends								
<2h vs. ≥2h	1.41 (0.87-2.29)	0.17	1.15 (0.68-1.96)	0.60	0.74 (0.53-1.04)	0.09	0.74 (0.51-1.08)	0.12
Sugar-sweetened beverages								
≥5 times/week vs. <once/week	**0.46 (0.28-0.77)**	**0.003**	**0.56 (0.32-0.99)**	**0.04**	0.93 (0.62-1.37)	0.70	0.98 (0.63-1.53)	0.94
3-4 times/week vs. <once/week	0.88 (0.52-1.50)	0.64	1.04 (0.59-1.85)	0.89	**0.65 (0.44-0.97)**	**0.03**	**0.62 (0.41-0.95)**	**0.03**
Once or twice a week vs. <once a week	0.64 (0.39-1.06)	0.08	0.75 (0.44-1.28)	0.29	0.79 (0.54-1.16)	0.23	0.80 (0.54-1.19)	0.27
Breakfast								
≥5 times/week vs. <5 times/week	1.40 (0.92-2.14)	0.12	1.08 (0.67-1.77)	0.75	1.17 (0.80-1.71)	0.41	1.05 (0.70-1.59)	0.81
Lunch								
≥5 times/week vs. <5 times/week	0.85 (0.26-2.75)	0.79	0.59 (0.17-2.08)	0.41	1.40 (0.75-2.60)	0.29	1.16 (0.58-2.32)	0.68
Dinner								

≥5 times/week vs. <5 times/week	**1.49 (1.02-2.16)**	**0.04**	1.48 (0.98-2.24)	0.06	1.42 (1.00-2.02)	0.05	**1.55 (1.01-2.37)**	**0.04**
Vegetables								
≥once a day vs. <once a day	1.09 (0.75-1.60)	0.65	0.88 (0.57-1.35)	0.56	0.75 (0.52-1.08)	0.13	0.74 (0.49-1.10)	0.14
Fruit								
≥once a day vs. <once a day	**1.46 (1.05-2.02)**	**0.02**	**1.67 (1.11-2.50)**	**0.01**	0.92 (0.69-1.23)	0.57	0.94 (0.67-1.33)	0.74
Milk and milk alternatives								
≥once a day vs. <once a day	**1.50 (1.08-2.07)**	**0.01**	1.19 (0.82-1.74)	0.35	1.01 (0.74-1.37)	0.97	1.01 (0.70-1.45)	0.97
Meeting water consumption recommendation								
Yes vs. no	1.48 (0.96-2.27)	0.07	1.42 (0.90-2.26)	0.14	0.96 (0.66-1.39)	0.82	1.05 (0.71-1.55)	0.82
Meeting egg consumption recommendation								
Yes vs. no	**1.59 (1.07-2.35)**	**0.02**	**1.60 (1.04-2.47)**	**0.03**	1.06 (0.75-1.49)	0.76	1.03 (0.71-1.49)	0.87

[a] Adjusted for age, gender, residence, only-child status in the family, boarding at school, average monthly living expenses, education level of parents and all lifestyle behaviors

Results in bold are statistically significant ($p < 0.05$)

Table 4 Logistic regression for identifying the combined effects of multiple lifestyle behaviors on academic grades

Variables	Inner urban high school students				Peri-urban high school students			
	Unadjusted		Model 1[a]		Unadjusted		Model 1[a]	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Multiple healthy lifestyle [b]	**1.22 (1.11-1.33)**	**<0.001**	**1.23 (1.11-1.35)**	**<0.001**	1.03 (0.96- 1.11)	0.42	1.03 (0.95-1.12)	0.45
Number of multiple healthy lifestyle [b]								
6 or less	Ref		Ref		Ref		Ref	
7-8	**1.54 (1.08- 2.21)**	**0.02**	**1.54 (1.06-2.24)**	**0.02**	1.02 (0.74- 1.40)	0.90	1.00 (0.72-1.39)	1.00
9-13	**3.05 (1.88- 4.95)**	**<0.001**	**3.25 (1.96-5.40)**	**<0.001**	1.02 (0.69-1.49)	0.94	1.03 (0.68-1.54)	0.68

[a] Adjusted for age, gender, residence, only-child status, boarding at school, average monthly living expenses, education level of parents and all lifestyle behaviors

[b] Includes physical activity before or after school, 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

Results in bold are statistically significant ($p < 0.05$)

DISCUSSION

Lifestyle behaviors of high school students appear to be associated with academic grades, and the cumulative effects of healthy lifestyle behaviors have a stronger positive association with their academic outcomes than the independent effects. These findings are particularly applicable to IUHSSs. Lifestyle behaviors are closely related to health, even education. The findings in this study revealed that health promotion initiatives targeting multiple lifestyle behaviors of high school students may have positive effects on 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.[31, 32] 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 weekdays and on weekends had positive effects on students' academic grades. By contrast, a negative association was found between weekdays' sleep duration adherence to the recommendation and academic grades among IUHSSs. Outstanding teachers in inner urban schools account for approximately two-thirds in Chongqing because of the regional and economic development.[33] 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 h or more sleep duration on weekdays. We speculated that these students who slept 8 h or more on weekdays may sleep at other times, such as during class or independent study time, leading to less study time. This could be the possible explanation for the negative

association between weekdays' sleep duration adherence to the recommendation and 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 to 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 positive effects on academic grades, and the association between weekends' 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 neutralize the negative effect of screen-based behaviors. No association 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 time behaviors compared with those from peri-urban high schools.

The results in the present study showed increased odds of high academic grades among PUHSSs who had regular dinner consumption, and no association was observed between breakfast 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, 6, 34] 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.[35] In the present 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,[36] and skipping dinner may affect the learning efficiency of evening classes, which may have an important effect on students' academic grades. This could be the reason that regularly eating dinner is positively correlated with academic grades. Health education related to regular meal patterns throughout the day must be conducted among high school students, particularly emphasizing 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 association with high academic grades. These results were largely similar to previous studies[8, 23, 37] that demonstrated that healthy dietary behaviors, such as frequent fruit consumption, were associated with high academic performance, whereas unhealthy dietary behaviors, including high frequency of SSBs consumption, were associated with low academic performance.

In this study, no association was found between physical activity before or after school, 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,[38-41] while, studies on physical activity and academic grades have produced mixed results.[42, 43] A previous study found a curvilinear relationship between physical activity and academic achievement, thereby suggesting that top sports students may have an additional extracurricular physical activity that displaced the time spent on academics.[44] Moreover, under the social, cultural, and educational background of China, many schools have reduced the physical education curriculum to maximize the study time on subjects important for exams.[18] This phenomenon is particularly prominent in high schools, where 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 met the recommendation for physical activity. Considering these factors, the cut-off values of the recommendation for daily 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 correlation 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] Choosing the appropriate method to assess physical activity of high school students is still needed to be explored in future studies, thereby to better explore its association with academic performance.

The findings demonstrated that the combined effects of multiple lifestyle behaviors resulted in a substantially higher likelihood of obtaining academic grades than the independent effects among IUHSSs, which was similar with 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] The present study complements and extends these important findings drawing 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 behaviors may have a greater positive effect on academic grades of high school students than those focusing on a single lifestyle behavior.

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 the present study. Second, lifestyle behaviors and academic grades were obtained by self-report that may introduce bias caused by self-enhancement and measurement flaws. Third, being an exploratory study, the questionnaire developed was not evaluated for its reliability and validity. However, questions on physical activity, sleep duration, and screen time were adapted from the China Health and Nutrition Survey,[45] and questions on dietary behaviors were adapted from Chinese Dietary Guideline 2016.[27] And expert input, pilot and review was done before implementation. The unvalidated measures in the questionnaire designed to measure the outcome variables may raise potential issues related to reliability. Further studies should consider validating the questionnaire prior to administration.

CONCLUSIONS

This study demonstrated that a correlation is found between the lifestyle behaviors of high school students and academic grades, and cumulative effects of healthy lifestyle behaviors have a stronger positive association with academic grades than the independent effects. These findings are particularly applicable to IUHSSs. The importance of multiple healthy lifestyle behaviors for 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.

Abbreviations

IUHSSs: inner urban high school students; PUHSSs: peri-urban high school students; SSBs: sugar-sweetened beverages; SPSS: Statistical Package for Social Sciences; OR: odds ratios; CI: confidence intervals.

Ethics approval and consent to participate

This study was reviewed and approved by the Ethics Committee of Chongqing Medical University. Informed consent was obtained from all participants, and they could voluntarily participate or withdraw from the study at any stage.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contributions

ZC carried out investigation, data analysis and wrote the paper. JX, HZ, HP provided help with the investigation and data collection. JX, AC, ZZ, SM provided the assistance in reviewing the paper. YZ provided guidance in study design, organized the investigation, and is the corresponding author. All authors approved the final manuscript.

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Supplementary Table 1. Description of questions in terms of lifestyle behaviors

Variable	Questions description
Physical activity	1) Do you participate in any physical exercises including relatively intense physical exercises, such as volleyball, soccer, and badminton before or after school each week? If "yes", how many times do you participate in any physical exercises? On average, for how long do you participate in these physical exercises each time? (hours: minutes)
	2) Do you participate in any physical exercises including relatively intense physical exercises, such as volleyball, soccer, and badminton at school each week? If "yes", how many times do you participate in any physical exercises? On average, for how long do you participate in these physical exercises each time? (hours: minutes)
Sleep duration	1) How many hours each day do you usually sleep including daytime and night-time on weekdays (hours: minutes)?
	2) How many hours each day do you usually sleep including daytime and night-time on weekends (hours: minutes)?
Screen time	1) On average, how long is your daily screen time, such as watching TV, online videos, using a computer or smart-phone, playing video games on weekdays (hours: minutes)?
	2) On average, how long is your daily screen time, such as watching TV, online videos, using a computer or smart-phone, playing video games on weekends (hours: minutes)?
Dietary behaviors	1) How often do you drink sugar-sweetened beverages? Response options were "every day", "5–6 times/week", "3–4 times/week", "1–2 times/week", "1–3 times/month", "<once/month".
	2) How often do you have breakfast? Response options were "every day", "5–6 times/week", "3–4 times/week", "1–2 times/month", "never".
	3) How often do you have lunch? Response options were "every day", "5–6 times/week", "3–4 times/week", "1–2 times/month", "never".

4) How often do you have dinner? Response options were “every day”, “5–6 times/week”, “3–4 times/week”, “1–2 times/month”, “never”.

5) How often do you eat vegetable? Response were “>once/day”, “4–6 times/week”, “2–3 times/week”, “once/week”, “<once/week”.

6) How often do you eat fruit? Response were “>once/day”, “4–6 times/week”, “2–3 times/week”, “once/week”, “<once/week”.

7) How often do you drink milk and alternatives? Response were “>once/day”, “4–6 times/week”, “2–3 times/week”, “once/week”, “<once/week”.

8) On average, how much is your daily water intake? Response options were “<800 milliliter”, “800–1100 milliliter”, “1100–1400 milliliter”, “1400-1500 milliliter”, “1500–1700 milliliter”.

9) On average, how many eggs do you eat every day? Response options were “three or more per day”, “two per day”, “one per day”, “3–4/week”, “1–2/week”, “never”.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	24
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-9
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-10
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	10-13
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13-19
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	20
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	24
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	20-24
Generalisability	21	Discuss the generalisability (external validity) of the study results	23-24
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	25

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Independent and Combined Associations between Multiple Lifestyle Behaviors 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 behaviors 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 0.32–0.99] and 0.63 [0.42–0.96], respectively). Among IUHSSs, meeting the recommendations for weekday screen time and egg consumption (1.57 [1.06–2.34] and 1.60 [1.04–2.47], respectively), and high frequency of fruit consumption (1.67 [1.11–2.50]) were significantly associated with high academic grades; meeting the recommendation for weekday sleep duration was unlikely to obtain high academic grades (0.46 [0.21–0.98]). Among PUHSSs, meeting the recommendations for weekend sleep duration (1.40 [1.02–1.93]) and eating dinner regularly (1.55 [1.01–2.37]) 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 behaviors were 3.25 times more likely to achieve high academic grades than IUHSSs with 1–6 healthy lifestyle behaviors (3.25 [1.96–5.40]). No significant associations were found in the

combined associations between multiple lifestyle behaviors and academic grades among PUHSSs ($p > 0.05$).

Conclusions: Correlations were observed between lifestyle behaviors and academic grades among high school students, and cumulative associations between multiple healthy lifestyle behaviors and academic outcomes appear to be stronger than the independent associations. These findings are particularly applicable to IUHSSs.

Keywords: Lifestyle behaviors; physical activity; sleep duration; screen time; dietary behaviors; academic grades; high school students; school health

Strengths and limitations of this study

- This study is novel as the independent and combined associations between multiple lifestyle behaviors 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 generalizable to other settings with economic disparities.
- Self-reported data such as lifestyle behaviors 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.

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 behaviors, sufficient physical activity and sleep, minimal screen time, etc., are positively associated with students' academic performance.[2-4] Studies examining the associations between dietary behaviors and academic achievement have typically focused on micronutrient intake,[5] dietary intakes,[6] and breakfast consumption.[2 7] Intake of certain micronutrients (i.e., 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 behaviors and academic performance is not isolated, and the combined associations between multiple healthy lifestyle behaviors and academic performance may be greater than any single behavior 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 standardized exams.[22] Faught et al. found that grade 5 students who met the recommendations for 7–9 lifestyle behaviors 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 so 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 behaviors 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 behaviors 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 et al. 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 behaviors.[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-urbanization refers to the dispersal of urban growth toward the rural surroundings of cities (urban sprawl), thereby creating landscapes that are characterized 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 behaviors and students' academic grades. Hence, this study aims to (1) explore the individual associations between multiple lifestyle behaviors (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 behaviors and academic grades in IUHSSs and PUHSSs. This study is expected to effectively promote multiple healthy lifestyle behaviors among high school students from areas with different economic levels and obtain a better understanding of the independent and combined associations between multiple lifestyle behaviors

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. Six to twelve 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 $N = (Z_\alpha{}^2 \times p \times q)/d^2$, 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 fifteen questions in terms of lifestyle behaviors (physical activity, sleep duration, screen time, and dietary behaviors) are presented in Supplementary Table 1. Healthy lifestyle behaviors 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 h a day and whose screen time is less than 2 h a day meet the physical activity guidelines for Chinese children and adolescents.[33] Physical activity was categorized into ≥1 h and <1 h, and daily screen time was categorized into ≥2 h and <2 h. Insufficient sleep was defined as less than 8 h a day for high school students, as recommended by the Chinese Dietary Guideline 2016.[34] Sleep duration was categorized into ≥8 h and <8 h. In terms of dietary behaviors, 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 behaviors.[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 dichotomized 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: ≤800 RMB, medium: 801–1200 RMB, and high: >1200 RMB), 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 version 21 (IBM Corporation, Chicago, IL, USA). 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 Inter-Quartile Range (IQR). Chi-square tests were conducted to examine the differences in lifestyle behaviors between IUHSSs and PUHSSs. The independent and combined associations between multiple lifestyle behaviors and academic grades were assessed through multivariate logistic regressions. Odds ratios (ORs) and their corresponding 95% confidence intervals (95% CI) were reported. An unadjusted logistic regression was used to assess the independent associations between multiple lifestyle behaviors 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 behaviors. 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 behaviors respectively. The effect of the number of healthy lifestyle behaviors was considered to assess the combined associations

between multiple lifestyle behaviors and academic grades. The total number of healthy lifestyle behaviors ranged from 1 to 13, and three categories of healthy lifestyle behaviors were constructed in accordance with the frequency distribution of the number of healthy lifestyle behaviors: low (1–6 healthy lifestyle behaviors, 40.0%), medium (7–8 healthy lifestyle behaviors, 38.8%), and high (9–13 healthy lifestyle behaviors, 21.2%). Treating the number of healthy lifestyle behaviors as both categorical and continuous variables, univariable and multivariable regression models were used to assess the cumulative associations between multiple lifestyle behaviors and academic grades. $p < 0.05$ (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 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 800 RMB. 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%.

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)

Lifestyle behaviors of participants

Table 2 shows the comparison of lifestyle behaviors between IUHSSs and PUHSSs. The percentages of students meeting the recommendations of lifestyle behaviors 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 behaviors varied between IUHSSs and PUHSSs except for physical activity at school, frequency of breakfast, dinner and vegetable intake, and water and egg consumption ($p < 0.05$).

Table 2 The comparison of lifestyles behaviors 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
Physical activity before or after school or on weekends					
<1 h	1,398 (94.4)	631 (93.1)	767 (95.5)	4.17	0.04
≥1 h	83 (5.6)	47 (6.9)	36 (4.5)		
Physical activity at school					
<1 h	1,192 (80.5)	547 (80.7)	645 (80.3)	0.03	0.86
≥1 h	289 (19.5)	131 (19.3)	158 (19.7)		
Sleep time on weekdays					
<8 h	1,321 (89.2)	643 (94.8)	678 (84.4)	41.30	<0.001
≥8 h	160 (10.8)	35 (5.2)	125 (15.6)		
Sleep time on weekends					

<8 h	437 (29.5)	171 (25.2)	266 (33.1)	11.04	<0.001
≥8 h	1044 (70.5)	507 (74.8)	537 (66.9)		
Screen time on weekdays					
≥2 h	276 (18.6)	157 (23.2)	119 (14.8)	16.85	<0.001
<2 h	1,205 (81.4)	521 (76.8)	684 (85.2)		
Screen time on weekends					
≥2 h	1,208 (81.6)	581 (85.7)	627 (78.1)	14.16	<0.001
<2 h	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	1,241 (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	1,425 (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	1,172 (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	1,171 (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	1,207 (81.5)	544 (80.2)	663 (82.6)	1.32	0.25
Yes	274 (18.5)	134 (19.8)	140 (17.4)		
Meeting egg intake recommendation					
No	1,141 (77.0)	508 (74.9)	633 (78.8)	3.17	0.08
Yes	340 (23.0)	170 (25.1)	170 (21.2)		

Logistic regression for identifying the independent and combined associations of multiple lifestyle behaviors and academic grades among IUHSSs and PUHSSs

The results of the logistic regression analysis for identifying the independent associations between multiple lifestyle behaviors 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 [1.10–1.77]) and eating dinner regularly (≥5 times/week vs. <5 times/week: OR = 1.47, 95% CI [1.11–1.95]) 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 [0.48–0.92]) 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 [1.06–2.34]) and daily egg consumption (OR = 1.60, 95% CI [1.04–2.47]), and high frequency of fruit consumption (≥once/week vs. <once/week: OR = 1.67, 95% CI [1.11–2.50]) were still significantly correlated with high academic grades; students who met the recommendations for sleep duration on weekdays (OR = 0.46, 95% CI [0.21–0.98]) and high frequency of SSBs consumption (≥5 times/week vs. <once/week: OR = 0.56, 95% CI [0.32–0.99]) were unlikely to obtain high academic grades. Among PUHSSs, meeting the recommendations for sleep duration on weekends (OR = 1.40, 95% CI [1.02–1.93]) and eating dinner regularly (≥5 times/week vs. <5 times/week: OR = 1.55, 95% CI [1.01–2.37]) 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 [0.42–0.96]) were unlikely to obtain high academic grades.

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

In the adjusted model, the number of healthy lifestyle behaviors among IUHSSs was positively associated with academic grades (OR = 1.23, 95% CI [1.11–1.35]). And IUHSSs who had 7–8 healthy lifestyle behaviors were more likely to obtain high academic grades than those who had 1–

6 healthy lifestyle behaviors (OR = 1.54, 95% CI [1.06–2.24]), IUHSSs who had 9–13 healthy lifestyle behaviors had 3.25 times higher odds of obtaining high academic grades than those who had 1–6 healthy lifestyle behaviors (OR = 3.25, 95% CI [1.96–5.40]). No combined association was found between lifestyle behaviors and academic grades among PUHSSs ($p > 0.05$).

Table 3 Logistic regression for identifying the independent associations between multiple lifestyle behaviors 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 [a]		Unadjusted		Adjusted [b]		Unadjusted		Adjusted [b]	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Physical activity before or after school or on weekends												
≥1 h vs. <1 h	0.77 (0.49–1.20)	0.25	0.83 (0.51–1.36)	0.46	1.00 (0.53–1.88)	0.99	1.50 (0.72–3.15)	0.28	0.51 (0.26. 1.01)	0.05	0.57 (0.27–1.18)	0.13
Physical activity at school												
≥1 h vs. <1 h	0.81 (0.62–1.06)	0.12	0.84 (0.63–1.11)	0.22	0.74 (0.49–1.09)	0.13	0.77 (0.48–1.23)	0.27	0.88 (0.62–1.25)	0.46	0.98 (0.66–1.44)	0.91
Sleep duration on weekdays												
≥8h vs. <8h	1.06 (0.75–1.49)	0.74	1.01 (0.70–1.45)	0.96	**0.47 (0.24–0.94)**	**0.03**	**0.46 (0.21–0.98)**	**0.04**	**1.56 (1.04–2.35)**	**0.03**	1.41 (0.92–2.18)	0.12
Sleep duration on weekends												
≥8h vs. <8h	**1.43 (1.14–1.80)**	**0.002**	**1.39 (1.10–1.77)**	**0.01**	1.35 (0.94–1.94)	0.11	1.38 (0.93–2.05)	0.11	**1.42 (1.05–1.91)**	**0.02**	**1.40 (1.02–1.93)**	**0.04**

Screen time on weekdays												
<2h vs. ≥2h	1.21 (0.93–1.58)	0.16	1.20 (0.90–1.59)	0.21	**1.73 (1.20–2.51)**	**0.004**	**1.57 (1.06–2.34)**	**0.02**	0.90 (0.61–1.35)	0.63	0.89 (0.58–1.36)	0.59
Screen time on weekends												
<2h vs. ≥2h	0.89 (0.68–1.16)	0.39	0.85 (0.64–1.59)	0.21	1.41 (0.87–2.29)	0.17	1.15 (0.68–1.96)	0.60	0.74 (0.53–1.04)	0.09	0.74 (0.51–1.08)	0.12
Sugar–sweetened beverages												
≥5 times/week vs. <once/week	0.74 (0.55–1.00)	0.05	**0.66 (0.48–0.92)**	**0.02**	**0.46 (0.28–0.77)**	**0.003**	**0.56 (0.32–0.99)**	**0.049**	0.93 (0.62–1.37)	0.70	0.99 (0.64–1.55)	0.98
3–4 times/week vs. <once/week	0.84 (0.62–1.14)	0.27	0.74 (0.54–1.02)	0.07	0.88 (0.52–1.50)	0.64	1.06 (0.60–1.90)	0.83	**0.65 (0.44–0.97)**	**0.03**	**0.63 (0.42–0.96)**	**0.03**
1–2 times/week vs. <once a week	0.81 (0.61–1.09)	0.16	0.74 (0.54–1.00)	0.05	0.64 (0.39–1.06)	0.08	0.78 (0.45–1.33)	0.36	0.79 (0.54–1.16)	0.23	0.81 (0.54–1.21)	0.30
Breakfast												
≥5 times/week vs. <5 times/week	1.27 (0.95–1.68)	0.10	1.07 (0.79–1.45)	0.65	1.40 (0.92–2.14)	0.12	1.08 (0.67–1.77)	0.75	1.17 (0.80–1.71)	0.41	1.05 (0.70–1.59)	0.81
Lunch												
≥5 times/week vs. <5 times/week	1.34 (0.78–2.30)	0.29	1.00 (0.56–1.79)	1.00	0.85 (0.26–2.75)	0.79	0.59 (0.17–2.08)	0.41	1.40 (0.75–2.60)	0.29	1.16 (0.58–2.32)	0.68
Dinner												

≥5 times/week vs. <5 times/week	**1.42 (1.10–1.83)**	**0.01**	**1.47 (1.11–1.95)**	**0.01**	**1.49 (1.02–2.16)**	**0.04**	1.48 (0.98–2.24)	0.06	1.42 (1.00–2.02)	0.05	**1.55 (1.01–2.37)**	**0.04**
Vegetables												
≥once a day vs. <once a day	0.88 (0.68–1.14)	0.34	0.84 (0.63–1.12)	0.23	1.09 (0.75–1.60)	0.65	0.88 (0.57–1.35)	0.56	0.75 (0.52–1.08)	0.13	0.74 (0.49–1.10)	0.14
Fruit												
≥once a day vs. <once a day	1.17 (0.95–1.46)	0.15	1.19 (0.92–1.53)	0.19	**1.46 (1.05–2.02)**	**0.02**	**1.67 (1.11–2.50)**	**0.01**	0.92 (0.69–1.23)	0.57	0.94 (0.67–1.33)	0.74
Milk and milk alternatives												
≥once a day vs. <once a day	1.31 (1.06–1.63)	0.01	1.22 (0.95–1.56)	0.12	**1.50 (1.08–2.07)**	**0.01**	1.19 (0.82–1.74)	0.35	1.01 (0.74–1.37)	0.97	1.01 (0.70–1.45)	0.97
Meeting water consumption recommendation												
Yes vs. no	1.17 (0.89–1.55)	0.26	1.20 (0.90–1.60)	0.21	1.48 (0.96–2.27)	0.07	1.42 (0.90–2.26)	0.14	0.96 (0.66–1.39)	0.82	1.05 (0.71–1.55)	0.82
Meeting egg consumption recommendation												
Yes vs. no	1.29 (1.00–1.67)	0.05	1.22 (0.93–1.61)	0.15	**1.59 (1.07–2.35)**	**0.02**	**1.60 (1.04–2.47)**	**0.03**	1.06 (0.75–1.49)	0.76	1.03 (0.71–1.49)	0.87

[a] 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 behaviors

[b] Adjusted for age, gender, residence, only-child status in the family, boarding school, average monthly living expenses, parental education level and all lifestyle behaviors

Results in bold are statistically significant ($p < 0.05$)

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

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

[a] Adjusted for school areas, age, gender, residence, only-child status, boarding school, average monthly living expenses, parental education level

[b] Adjusted for age, gender, residence, only-child status, boarding school, average monthly living expenses, parental education level

[c] 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

Results in bold are statistically significant ($p < 0.05$)

DISCUSSION

Lifestyle behaviors of high school students appear to be associated with academic grades, and the cumulative associations between multiple healthy lifestyle behaviors and their academic outcomes seem to be stronger than the independent associations. These findings are particularly applicable to IUHSSs. Lifestyle behaviors are closely related to education, the findings in this study revealed that multiple healthy lifestyle behaviors 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. Outstanding teachers in inner urban schools account for approximately two-thirds of all teachers in Chongqing due to regional and economic development.[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 h or more sleep duration on weekdays. We speculated that IUHSSs who slept 8 h 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 to 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 neutralize the negative association between screen-based behaviors 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 behaviors compared with those from peri-urban high schools.

The results in the present 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 the present 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 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 emphasizing 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 behaviors, such as frequent fruit consumption, were associated with high academic performance, whereas unhealthy dietary behaviors, 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 maximize the study time on subjects important 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 behaviors

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 behaviors 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. The present 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 behaviors may have a greater positive effect on the academic grades of high school students than those focusing on a single lifestyle behavior.

Regarding the potential mechanisms on the associations between lifestyle behaviors and academic grades, a previous study showed that adolescence is a critical period in which there is considerable re-organisation 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 BDNF (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. Firstly, 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 the present study. Secondly, lifestyle behaviors and academic grades were obtained by self-report that may introduce bias caused by self-enhancement and measurement flaws. Thirdly, academic grades in this study is a comprehensive ranking of all compulsory subjects, however, students' lifestyle behaviors could have different influences on different subjects,[23] the independent and combined associations between multiple lifestyle behaviors 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). Fourthly, 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 behaviors 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 behaviors and academic grades may raise potential issues related to reliability. Further studies should consider using a verified questionnaire or validating the questionnaire before administration. Fifthly, 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 generalizable 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 behaviors of high school students and academic grades, and cumulative associations between multiple healthy lifestyle

behaviors and academic grades appear to be stronger than the independent associations. These findings are particularly applicable to IUHSSs. The importance of multiple healthy lifestyle behaviors 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.

Abbreviations

IUHSSs: inner urban high school students; PUHSSs: peri-urban high school students; SSBs: sugar-sweetened beverages; SPSS: Statistical Package for Social Sciences; OR: odds ratios; CI: confidence intervals.

Ethics approval and consent to participate

This study was reviewed and approved by the Ethics Committee of Chongqing Medical University (record number 2016001). Informed consent was obtained from all participants, and they could voluntarily participate or withdraw from the study at any stage.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contributions

ZC carried out investigation, data analysis and wrote the paper. JX, HZ, HP provided help with the

investigation and data collection. JX, AC, ZZ, SM provided the assistance in reviewing the paper. YZ provided guidance in study design, organized the investigation, and is the corresponding author. All authors approved the final manuscript.

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Supplementary Table 1. Description of questions in terms of lifestyle behaviors

Variable	Questions description
Physical activity	1) Do you participate in any physical exercises including relatively intense physical exercises, such as volleyball, soccer, and badminton before or after school or on weekends each week? If "yes", how many times do you participate in any physical exercises? On average, for how long do you participate in these physical exercises each time? (hours: minutes)
	2) Do you participate in any physical exercises including relatively intense physical exercises, such as volleyball, soccer, and badminton at school each week? If "yes", how many times do you participate in any physical exercises? On average, for how long do you participate in these physical exercises each time? (hours: minutes)
Sleep duration	1) How many hours each day do you usually sleep including daytime and night-time on weekdays (hours: minutes)?
	2) How many hours each day do you usually sleep including daytime and night-time on weekends (hours: minutes)?
Screen time	1) On average, how long is your daily screen time, such as watching TV, online videos, using a computer or smart-phone, playing video games on weekdays (hours: minutes)?
	2) On average, how long is your daily screen time, such as watching TV, online videos, using a computer or smart-phone, playing video games on weekends (hours: minutes)?
Dietary behaviors	1) How often do you drink sugar-sweetened beverages? Response options were "every day", "5–6 times/week", "3–4 times/week", "1–2 times/week", "1–3 times/month", "<once/month".
	2) How often do you have breakfast? Response options were "every day", "5–6 times/week", "3–4 times/week", "1–2 times/month", "never".
	3) How often do you have lunch? Response options were "every day", "5–6 times/week", "3–4 times/week", "1–2 times/month", "never".

4) How often do you have dinner? Response options were “every day”, “5–6 times/week”, “3–4 times/week”, “1–2 times/month”, “never”.

5) How often do you eat vegetable? Response options were “>once/day”, “4–6 times/week”, “2–3 times/week”, “once/week”, “<once/week”.

6) How often do you eat fruit? Response options were “>once/day”, “4–6 times/week”, “2–3 times/week”, “once/week”, “<once/week”.

7) How often do you drink milk and alternatives? Response options were “>once/day”, “4–6 times/week”, “2–3 times/week”, “once/week”, “<once/week”.

8) On average, how much is your daily water intake? Response options were “<800 milliliter”, “800–1100 milliliter”, “1100–1400 milliliter”, “1400-1500 milliliter”, “1500–1700 milliliter”.

9) On average, how many eggs do you eat every day? Response options were “three or more per day”, “two per day”, “one per day”, “3–4/week”, “1–2/week”, “never”.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-7
Objectives	3	State specific objectives, including any prespecified hypotheses	5-7
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-10
Bias	9	Describe any efforts to address potential sources of bias	26
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10-11
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-14
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	10-14

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	17-20
		(*b*) Report category boundaries when continuous variables were categorized	20
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	21
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	26
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	21-26
Generalisability	21	Discuss the generalisability (external validity) of the study results	26
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	27

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.