The Association Between Living Environmental Factors and Adolescents' Body Weight

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Abstract

Background

The effect of living environment on public health has received increasingly scholarly attention. This study aims to explore the relationship between adolescents' body weight and their living environmental factors.

Methods

This cross-sectional study comprised 1362 middle-school students from Nanjing and 826 from Changzhou in China. We further collected information on living environmental factors based on their home address and ran a univariate logistic analysis for each variable to explore potential correlations.

Results

Approximately 25% (n=303) of students from Nanjing and 26% (n=205) of students from Changzhou were excessively overweight. In Nanjing, students' BMI (Body Mass Index) showed a strong negative correlation with the number of sports venues in their neighbourhood (OR: 0.61, 95%CI: 0.40-0.94). In Changzhou, we observed a positive correlation between adolescents' body weight and the number of bus stops in their neighbourhood (OR:1.53, 95%CI:1.06-2.21).

Conclusions

The living environment factors were independently associated with teenagers' excessive body weight, and the environmental risk factors might be associated with political management. Public policies change students' living environments, finally affecting individual behaviours and health outcomes.

Introduction

With the recent global urbanization and the continuing industrial development, the number of obese children has demonstrated a ten-fold increase from approximately 11 million in 1975 to 124 million in 2016, with additional 216 million overweight individuals around the world.¹ Regretfully, over the recent three decades, little progress has been achieved in treating or preventing the excessive body weight.² It is reported that in China, the prevalence of childhood obesity increased from 0.5% in 1985 to 7.3% in 2014, with a rising prevalence of overweight from 2.1% to 12.2%.³ It is therefore obligatory for scholars to rethink the strategies for obesity and overweight prevention and treatment.

According to previous statistical analysis, overweight and obese individuals were divided into different groups, leading to underestimating the sever of the overweight issues.⁴ Policymakers and doctors just paid attention to the severe obesity patients, ignoring health-care costs incurred by overweight group. There were only a few overweight patients to link their terrible physiological situations with their excessive BMI.⁴ Overweight students and their parents, to some extent, did not realize that excessive body weight related to multiple adverse health outcomes, including an elevated risk of developing type 2

diabetes, cardiovascular diseases, and other physical and mental illnesses.^{5, 6} The economic burden of overweight and obesity has also reached at US\$2 trillion, matching that of smoking and all military conflict.⁷ Therefore, the whole range of excessive BMIs should be considered, as opposed to simply concentrating on the obesity group.

Considering that the individual genetic and lifestyle factors attribute in part to the global increase in the prevalence of obesity and overweight in recent years, the multifactorial nature of overweight has attracted much attention to researching on(?) modifiable environmental characteristics.^{8, 9} Living environmental factors influence students' life behaviours and affect their energy intake and consumption, leading to different health outcomes. It is reported that an increased number of fitness facilities were associated with a reduction in teenagers' body weight, which provided more opportunities to access to recreational facilities to increase their daily exercise.^{10, 11} Pineda E emphasized the distance to the nearest fast-food restaurant elevated the risk of overweight and obesity, especially in low-family-income students.¹² A straightforward hypothesis is that the environmental characteristics, including the presence of cycle paths, sidewalks, active public transportation¹³, green spaces, and the degree of urbanization, are related to childhood body weight. In particular, access to open green spaces led to increased physical activities as well as decreased screen time which would perhaps explain the reduced risk of students' excessive BMI.¹⁴⁻¹⁶

Although the significant relationship between the environmental factors and adolescents' excessive body weight has been well addressed by the current research, there are still several essential aspects that have not been scrutinized, such as parents' attitudes towards students doing outdoor activities and influence from large scale municipal works projects. The majority of studies on the relationship between the built environment and childhood excessive body weight, in addition, were mainly conducted in developed countries.¹⁷ It was worthy to note that China, a nation with a highly authoritative government, has equipped with the fast-growing food delivery industry, the prosperity of sports marketing, full capacity running transportation system; this has resulted in different opportunities to access to health food or changing citizens' life behaviours.^{17, 18} However, to date, there has been little research systematically assessing the relationship between living environmental factors and childhood body weight in China, which is valuable for future environment design and city planning to reverse the tide of childhood excessive body weight.

In light of the foregoing, this study, focusing on the whole excessive body weight children, examines the living environmental factors in an urban Chinese context and evaluates how these living environmental factors relate to the risk of childhood excessive BMI. Findings may potentially contribute to the body of knowledge and inform the development of multi-sectoral intervention strategies.

Methods

Study design and participants

We conducted this population-based study in Nanjing and Changzhou, with a combined population of more than 1.5 million residents aged under 15 years old. These two cities have a similar economic and cultural background, but Nanjing has a larger population and more prosperous built environment setting compared with Changzhou. Therefore, we ran a parallel analysis for each city respectively.

The cross-sectional survey was conducted in all districts in Changzhou and 9 districts in Nanjing. We randomly selected one junior high school from each district, then chose three classes from each school, and one class for each grade (i.e., Year 7-9). We excluded residential students who lived in the school dormitories and those participants without any information on commuting to school, yielding a sample size of 1911 students from Nanjing and 1244 from Changzhou. We further excluded participants who did not provide complete data on home address, weight, and height. The final study population comprised 1362 students from Nanjing and 826 from Changzhou.

Ethics

Before we conducted this survey, the written consent from participants and their parents were already obtained. Moreover, all information regarding the participants and their families remained confidential. The data were collected from June to October in 2018, and this study was approved by China Institute of Sports Science ethics committee (Ethical code: CISSIRD-201604).

Study outcome

We categorized Body Mass Index (BMI) of the study participants into normal weight group and excessive body weight group (combined overweight and obesity) according to the latest *State Students Health Standards*.¹⁹ We excluded a total of 182 underweight students (127 from Nanjing, 55 from Changzhou) from the analysis. We ran sensitivity analysis and did not find material change.

Study factors

In order to explore the impact of the domestic living environment on childhood excessive body weight, we used the Geography Information System (ArcGIS 9.1) to calculate the number of bus stops, scenic spots, sports venues, food spots, and recreational areas in 500 meters distance from their home address. In this research, beside **bus stops**, we defined another four aspects in advance, **food spots** including restaurants, cafeteria, bubble tea stores, coffee shops, and street food spots; **scenic spots** covering parks, historical place, and ancient temple; **sports venues** including sports facilities centre, public sports playgrounds, fitness trail, and stadium; **recreation areas** covering shopping centers, zoos, museums, carnie, and aquaria. We further categorized the number of bus stops as over 20 or not, scenic sites as over 3 or not, and the availability of sports venues and recreational areas as yes or no.

We also collected the controlling factors to modify the results, such as age, gender, daily physical activities, intake frequency of sweetened food and sugar beverage drink, parental BMI, parental smoking

history, overall satisfaction with living environments, fitness time of parents themselves, family economic status, and so on, which might affect teenagers' body weight.

Statistical Analysis

We employed Stata 14.0 for all data analysis. The number and proportion of variables of interest among the sampled population were calculated. We conducted multiple imputation for missing values before running a univariate logistic analysis for each environmental variable and the outcome to explore the strength of the association. Environmental variables of the p-value of less than 0.25 for the crude odds ratio (OR) were modelled with multivariate logistic regression for each city respectively, in order to control for other covariates. Prior confounders included age, sex and other sociodemographic variables. We used the likelihood ratio test to test if the difference between the full model and the reduced model was statistically significant. We also used mixed-effect logistic models for each city for sensitivity analysis to examine if regional (district-level) variabilities would contribute to the childhood overweight. We observed little clustering effects with negligible intraclass coefficients. We considered a p-value of 0.05 as statistically significant.

Results

Excessive body weight was more prevalent in males than females (31% vs 18% in Nanjing, 31% vs 20% in Changzhou) (**Tables 1 and 2**). The prevalence of excessive body weight increased with the frequency of consuming barbeque food among Nanjing students (**Table 1**), which was not observed among Changzhou students (**Table 2**).

Study Site 1: Nanjing

More students had parents with normal BMI range, less parental encouragement for exercise (51.4% n=635), a father with smoking history (61.1%, n=754), and were satisfied with their living environment (78.6%, n=971 among students; 75.3%, n=930 among their parents). Students lived in a residential address with over 20 bus stops (90.6%, n=1119), over 3 scenic sites (75%, n=926), with any sport venues (88.4%, n=1092) and any recreational areas (91.6%, n=1131) within 500-meter distance, accounted for a large majority of the study population. The median number of food outlets was 207 with a range from 0 to 2179.

Compared with students residing in a place without any sport venues, those who having access to sport venues near their residential places are less likely to gain excessive body weight (OR: 0.61, 95%CI: 0.40-0.94, p=0.027), after controlling for other factors (**Table 3**). In addition to the sport venues, male students (OR: 2.01, 95%CI: 1.49-2.71, p<0.0001), those having an excessive BMI parent (OR: 1.87, 95%CI: 1.38-2.52, p<0.0001 for father; OR: 1.78, 95%CI: 1.20-2.62, p=0.004 for mother), from lower socioeconomic background (OR: 0.70, 95%CI: 0.52-0.94, p=0.017), having higher frequency of barbeque food consumption (OR: 1.18, 95%CI: 1.01-1.38, p=0.037), and having medium strength activity of longer than 30 minutes (OR: 1.40, 95%CI: 1.04-1.90, p=0.025) were more likely to gain excessive body weight.

Study Site 2: Changzhou

In contrast, more students had parents with normal BMI range, less parental encouragement for exercise (54.2% n=432), fathers without smoking history (55.3%, n=322), and were satisfied with their living environment (91.3%, n=728 for students themselves; 81.6%, n=650 for their parents). Students lived in a residential address with over 20 bus stops (70.3%, n=560) and over 3 scenic sites (93.4%, n=744) accounted for the majority of the study population. Only six students resided in a place without any recreational areas. The median number of food outlets was 362 with a range from 22 to 1069.

Univariate analysis identified that those were males, either having an excessive BMI parent or residing in a place with over 20 bus stops within 500-meter distance, were positively associated with being excessive body weight ($p < 0.05$) (**Table 2**). The effects of these factors remained after controlling for other covariates (**Table 4**). Using multilevel mixed-effect models, we did not observe statistically significant regional variations at district levels (interclass correlation < 0.01 , $p > 0.05$).

Discussion

In this geographically diverse sampling of adolescents from the junior high schools, our results illustrated consistent evidence that residential environment factors were independently correlated with overweight. It was interesting to note that the level of transportation systems had an impact on Changzhou students, and the availability of sports venues on Nanjing students, which was in line with the development of city policies and guidelines in recent years.²⁰ Nanjing was the host city for the 2nd Summer Youth Olympic Game in 2014, and the local administrations were dedicated to developing the best global sports and entertainment venues as well as enhance the sports culture. After the Game, its heritage was transferred for public activities and the culture prevailed.²¹ According to the 2016 government report, additional efforts would be invested to mend fitness trails to grow from 420 kilometers to 863 kilometers, provide 691 playgrounds, and establish 341 sports facilities during the period from 2017 to 2035.²¹ Lacking comparable sports venues and culture, Changzhou is famous for its well-organized public transportation system with low bus fare, expanding public transportation network, and high daily passenger capacity.²² However, our findings were contrary to the previous results that more numbers of bus stops would lead to a high prevalence of childhood excessive body weight.²³ The convenient public transportation system did not show a positive impact on individuals' traveling habits. However, it is beyond the capacity of this brief research to fully contextualize this complex issue and further qualitative research is needed to explore the hidden reasons for this weird phenomenon.

Mendenhall argued that macro-level political elements would influence chronic diseases on their clustering at the population level and consequently would affect syndrome pathologies at the individual level.²⁴ This implies that decisive policies are able to reverse the upwards trend of overweight or obesity by modifying civil planning and access to facilities, especially for vulnerable younger children with constrained resources.²⁵ The young adolescents' excessive body weight not only relates to simply eating and exercising habits, but also encompasses important aspects of social and environmental situations,

which might exacerbate their health outcomes and inequity.^{25, 26} Facing with limited access to resources due in part to family financial burden and personal study load, provision of free sports facilities, ideally near residential neighbourhood, might be effective to offer extra opportunities for adolescents to attain the unstructured exercise during their off-school time.²⁷ Additional exercise is necessary to finally make up the time of daily active exercise to catch up with the recommended levels of physical activities, which is currently not met in school-aged adolescents by large.²⁸

It was worthy to notice that the Changzhou subway project was conducted from April 2015, and line 1 was finished in Sep 2019, the completion of line 2 will be at the beginning of 2021. In the former investments, researchers indicated the subway construction process was the “predawn darkness” for traffic system, and the long period of metro construction would bring numerous environmental and social issues for this city.²⁹ Usually, subways lines have coincided with the urban traffic-intensive hubs. It was inevitable that construction enclosure occupied the parts of crossroad and motorway, and damaged some traffic lights, decreasing the surrounding safety.³⁰ Subway construction posed a huge extra burden on surface transportation, causing traffic congestion. Chaos traffic surroundings set barriers for citizens to access to public transportation, which might influence their health behaviors towards more active lifestyles, with the implication of more likely to be excessive body weight.³⁰ Based on local government 2018 reports, the car ownership per capita of Nanjing and Changzhou was almost the same, 0.25 and 0.24 per capita respectively.³¹ It was also noteworthy the nearly perfect public transportation system did not create the walkability of residential surroundings and decrease personal car-dependence.

In addition to the built environment factors, other factors, including parental excessive BMI, family income, being male, and barbeque food consumption, were found associated with young adolescents’ excessive body weight, which were consistent with previous findings.^{12, 32-34} For example, genetic factors influenced fat distribution as well as daily energy expenditure, energy intake, and habitual physical activities.¹² It is also speculated that families with higher incomes could have more access to healthy food and live healthier lifestyles.³⁵ However, the lack of comparable exposure data limited our ability to confirm such relationships. Other limitations include the lack of crime data (for the security reason, we did not gain the data from police departments) in relation to young adolescents’ residential areas, we were not able to explore whether satisfaction with neighbourhood safety would impact on young adolescents’ physical activities.³⁶ Moreover, the nature of cross-sectional data limits the causal-effect inference, and therefore results should be interpreted with caution. Further qualitative researches are needed to explore the motivations and hidden reasons for personal behaviours.

Excessive body weight in school-aged children in China remains a public health issue. Further efforts to reduce the childhood excessive body weight are warranted.³⁷ Future studies using trial data or investigation of individual and parental beliefs and behaviours can further explore the role of environmental factors and the effects of local policies in particular availability of sports venues and access to the public transportation network in relation to childhood excessive body weight.

Conclusion

In conclusion, this study indicates that the living environment factors were independently associated with excessive body weight. The findings among students from Nanjing and Changzhou varied due to different local policies. Therefore, we hypothesis that, to some extent, the environmental risk factors, e.g. numbers of bus stations and sports venues, might be associated with political management, which will finally affect individual behaviours and personal health outcomes. Given the fact that teenagers' excessive body weight is still a significant health concern, further researches and proactive measures are required to attenuate the problem.

Abbreviations

Not applicable

Declarations

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Availability of data and material

Datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by China Institute of Sports Science ethics committee, Ethical code: CISSIRD-201604. Before we conducted this survey, the written consent from participants and their parents were already obtained. Moreover, all information regarding the participants and their families remained confidential.

Competing interests

No competing financial interests exist.

Consent for publication

This manuscript is approved by all authors for publication

Authors' contributions

All authors provided critical input and approved the final version. Wei Du, Siyi Huang and Hanwen Zhang were responsible for the study design and data collecting. Sasa conducted data analysis and interpretation. Siyi Huang and Xinyi Wu finished the literature review aspects. Based on the suggestion from Wei Du, Siyi Huang, Sasa and Xinyi Wu wrote the first draft of this manuscript. Chongmin Jiang, Yan Zhao, and Jie Yang provided the critical revision of the manuscript for important intellectual content.

References

1. WHO. New global estimates of child and adolescent obesity released on World Obesity Day [Internet]. Geneva Switzerland: WHO; 2017 [cited 2020 2020 May 31]. Available from: <https://www.who.int/end-childhood-obesity/news/new-estimate-child-adolescent-obesity/en/>.
2. Kleinert S, Horton R. Rethinking and reframing obesity. *The Lancet*. 2015;385:2326-8.
3. Ma G. China Obesity Report Beijing, China: People's Medical Publishing House;; 2017.
4. James WPT, McPherson K. The costs of overweight. *The Lancet Public Health*. 2017;2:e203-e4.
5. Li D-K, Chen H, Ferber J, et al. Infection and antibiotic use in infancy and risk of childhood obesity: a longitudinal birth cohort study. *The lancet Diabetes & endocrinology*. 2016;5:18-25.
6. Jaacks LM, Vandevijvere S, Pan A, et al. The obesity transition: stages of the global epidemic. *The Lancet Diabetes & Endocrinology*. 2019;7:231-40.
7. Dobbs R, Sawers C, Thompson F, et al. Overcoming obesity: an initial economic assessment. A discussion paper by the McKinsey Global Institute. 2014;
8. Pelusi C, Altieri P, Gambineri A, et al. Behavioral, socio-environmental, educational and demographic correlates of excess body weight in Italian adolescents and young adults. *Nutrition, Metabolism and Cardiovascular Diseases*. 2018;29:279-89.
9. Spilkova J. Teenage overweight and obesity: A pilot study of obesogenic and obesoprotective environments in the Czech Republic. *Moravian geographical reports*. 2016;24:55-64.
10. Villanueva R, Albaladejo R, Astasio P, et al. Socio-economic environment, area facilities and obesity and physical inactivity among children. *The European Journal of Public Health*. 2015;26:267-71.
11. Xu F, Chepyator-Thomson J, Liu W, et al. Association between social and environmental factors and physical activity opportunities in middle schools. *European Physical Education Review*. 2010;16:183-94.
12. Pineda E, Swinburn B, Sassi F. Effective school food environment interventions for the prevention of childhood obesity: systematic review and meta-analysis. *The Lancet*. 2019;394: .
13. Wen LM, Rissel C. Inverse associations between cycling to work, public transport, and overweight and obesity: findings from a population based study in Australia. *Preventive medicine*. 2008;46:29-32.

14. Evans GW, Jones-Rounds ML, Belojevic G, et al. Family income and childhood obesity in eight European cities: the mediating roles of neighborhood characteristics and physical activity. *Social science & medicine*. 2012;75:477-81.
15. Carson V, Kuhle S, Spence JC, et al. Parents' perception of neighbourhood environment as a determinant of screen time, physical activity and active transport. *Canadian Journal of Public Health*. 2010;101:124-7.
16. Veitch J, Timperio A, Crawford D, et al. Is the neighbourhood environment associated with sedentary behaviour outside of school hours among children? *Annals of behavioral medicine*. 2011;41:333-41.
17. An R, Shen J, Yang Q, et al. Impact of built environment on physical activity and obesity among children and adolescents in China: a narrative systematic review. *Journal of sport and health science*. 2019;8:153-69.
18. Zhang X, van der Lans I, Dagevos H. Impacts of fast food and the food retail environment on overweight and obesity in China: a multilevel latent class cluster approach. *Public health nutrition*. 2012;15:88-96.
19. The Ministry of Education of the People's Republic of China. Student Physical Health Standard. Beijing China: The Ministry of Education of the People's Republic of China; 2014 Jul 07. 8 p.
20. Malik VS, Willett WC, Hu FB. Global obesity: trends, risk factors and policy implications. *Nature Reviews Endocrinology*. 2012;9:13-27.
21. Nanjing Government. "Nanjing City Sports Facilities Special Plan" released in 2035, there will be 1 football field for every 10,000 people [Internet]. Nanjing China: Nanjing Government; 2019 [cited 2020 May 31]. Available from: http://www.nanjing.gov.cn/mszx/201908/t20190802_1615473.html.
22. Yang H, Zhang B, Ma J. Daily passenger capacity of Changzhou BRT reached 300,000 person-times. People [Internet]. 2015 Dec 04 [cited 2020 May 31]; Livelihood [about 1 p.]. Available from: <http://js.people.com.cn/n/2015/1204/c360302-27249305.html>
23. Chen C, Menifield CE. An ecological study on means of transportation to work and obesity: evidence from US states. *Transport policy*. 2017;59:174-80.
24. Mendenhall E. Syndemics: a new path for global health research. *The Lancet*. 2017;389:889-91.
25. Giles-Corti B, Vernez-Moudon A, Reis R, et al. City planning and population health: a global challenge. *The lancet*. 2016;388:2912-24.
26. Voss L, Hosking J, Metcalf B, et al. Children from low-income families have less access to sports facilities, but are no less physically active: cross-sectional study (EarlyBird 35). *Child: care, health and development*. 2008;34:470-4.
27. Floyd MF, Bocarro JN, Smith WR, et al. Park-based physical activity among children and adolescents. *American journal of preventive medicine*. 2011;41:258-65.
28. Chen P, Wang D, Shen H, et al. Physical activity and health in Chinese children and adolescents: expert consensus statement (2020). *British Journal of Sports Medicine* 2020; .

29. Nie H. The Impact of Subway Construction on Urban Traffic. *Journal of Transport Information and Safety*. 2011;29:65-8,72.
30. Xue X, Zhang R, Zhang X, et al. Environmental and social challenges for urban subway construction: An empirical study in China. *International Journal of Project Management*. 2015;33:576-88.
31. Eastday. Automobile ownership of prefecture-level cities in Jiangsu in 2018 [Internet]. Shanghai China: Eastday; 2020 Jan 21 [cited 2020 May 31]. Available from: <https://mini.eastday.com/a/200121025319835.html>.
32. De Vet E, De Ridder D, De Wit J. Environmental correlates of physical activity and dietary behaviours among young people: a systematic review of reviews. *Obesity reviews*. 2011;12:e130-e42.
33. Meng X-R, Song J-Y, Ma J, et al. Association study of childhood obesity with eight genetic variants recently identified by genome-wide association studies. *Pediatric research*. 2014;76:310-5.
34. Carroll-Scott A, Gilstad-Hayden K, Rosenthal L, et al. Disentangling neighborhood contextual associations with child body mass index, diet, and physical activity: the role of built, socioeconomic, and social environments. *Social science & medicine*. 2013;95:106-14.
35. Singh GK, Siahpush M, Kogan MD. Neighborhood socioeconomic conditions, built environments, and childhood obesity. *Health affairs*. 2010;29:503-12.
36. Creatore MI, Glazier RH, Moineddin R, et al. Association of neighborhood walkability with change in overweight, obesity, and diabetes. *Jama*. 2016;315:2211-20.
37. Gortmaker SL, Swinburn BA, Levy D, et al. Changing the future of obesity: science, policy, and action. *The Lancet*. 2011;378:838-47.

Tables

Table 1. Study population characteristics, by Body Mass Index – normal vs overweight, Nanjing

	BMI			Univariate Analysis	
Variables	<i>Normal</i>	<i>Overweight</i>	<i>Total</i>		
	No. (%)	No. (%)	No. (%)	<i>Crude OR [95%CI]</i>	<i>P</i>
Age					
≤12	232 (77)	69 (23)	301 (24.4)	—	
13	333 (72)	127 (28)	460 (37.2)	1.28 [0.9,1.8]	0.15
14	244 (79)	66 (21)	310 (25.1)	0.91 [0.6,1.3]	0.63
≥15	123 (75)	41 (25)	164 (13.3)	1.12 [0.7,1.7]	0.62
Sex					
Female	514 (82)	113 (18)	627 (50.8)	—	
Male	418 (69)	190 (31)	608 (49.2)	2.07 [1.6,2.7]	<0.0001
<i>Dietary and Exercise factors</i>					
Medium strength activity					
≤30 min/d	600 (78)	172 (22)	772 (62.5)	—	
> 30 min/d	332 (72)	131 (28)	463 (37.5)	1.38 [1.1,1.8]	0.018
Sweeten food				1.02 [0.9,1.1]	0.72
never	232 (75)	76 (25)	308 (24.9)		
1-2 times/month	278 (77)	83 (23)	361 (29.2)		
1-2 times/week	250 (74)	89 (26)	339 (27.4)		
2-3 times/week	114 (75)	39 (25)	153 (12.4)		
every day	36 (77)	11 (23)	47 (3.8)		
unknown	22 (81)	5 (19)	27 (2.2)		
BBQ				1.19 [1,1.4]	0.012
never	389 (78)	109 (22)	498 (40.3)		
1-2 times/month	358 (75)	117 (25)	475 (38.5)		
1-2 times/week	106 (71)	43 (29)	149 (12.1)		
2-3 times/week	46 (70)	20 (30)	66 (5.3)		
every day	10 (59)	7 (41)	17 (1.4)		
unknown	23 (77)	7 (23)	30 (2.4)		

Snacks				0.98 [0.9,1.1]	0.77
never	188 (73)	68 (27)	256 (20.7)		
1-2 times/month	213 (76)	66 (24)	279 (22.6)		
1-2 times/week	256 (77)	78 (23)	334 (27)		
2-3 times/week	148 (75)	50 (25)	198 (16)		
every day	96 (75)	32 (25)	128 (10.4)		
unknown	31 (78)	9 (23)	40 (3.2)		
Family factors					
Economic status				0.76 [0.6,1]	0.03
lower	409 (73)	148 (27)	557 (45.1)		
medium	407 (78)	117 (22)	524 (42.4)		
higher	33 (87)	5 (13)	38 (3.1)		
unknown	83 (72)	33 (28)	116 (9.4)		
Father's BMI					
normal	517 (80)	131 (20)	648 (52.5)	—	
overweight	271 (68)	126 (32)	397 (32.1)	1.83 [1.4,2.4]	<0.0001
underweight	31 (79)	8 (21)	39 (3.2)	1.02 [0.5,2.3]	0.96
unknown	113 (75)	38 (25)	151 (12.2)	1.33 [0.9,2]	0.181
Mother's BMI					
normal	643 (77)	187 (23)	830 (67.2)	—	
overweight	98 (64)	55 (36)	153 (12.4)	1.93 [1.3,2.8]	<0.0001
underweight	84 (82)	19 (18)	103 (8.3)	0.78 [0.5,1.3]	0.35
unknown	107 (72)	42 (28)	149 (12.1)	1.35 [0.9,2]	0.13
Parents' encouragement for exercise					
less encourage	473 (74)	162 (26)	635 (51.4)	—	
more encourage	401 (77)	120 (23)	521 (42.2)	0.88 [0.7,1.2]	0.38
unknown	58 (73)	21 (27)	79 (6.4)		
Father fitness time					
Less	469 (76)	145 (24)	614 (49.7)	—	

more	273 (75)	90 (25)	363 (29.4)	1.02 [0.8,1.4]	0.92
unknown	190 (74)	68 (26)	258 (20.9)		
Mother fitness time					
less	459 (76)	146 (24)	605 (49)	—	
more	391 (75)	133 (25)	524 (42.4)	1.05 [0.8,1.4]	0.74
unknown	82 (77)	24 (23)	106 (8.6)		
Father smoking					
no	346 (80)	87 (20)	433 (35.1)	—	
yes	552 (73)	202 (27)	754 (61.1)	1.46 [1.1,1.9]	0.01
unknown	34 (71)	14 (29)	48 (3.9)	1.64 [0.8,3.2]	0.15
Mother smoking					
no	858 (76)	270 (24)	1128 (91.3)	—	
yes	8 (67)	4 (33)	12 (1)	1.59 [0.5,5.3]	0.45
unknown	66 (69)	29 (31)	95 (7.7)	1.4 [0.9,2.2]	0.15
<i>Environmental factors</i>					
Bus stops					
≤20	88 (76)	28 (24)	116 (9.4)	—	
>20	844 (75)	275 (25)	1119 (90.6)	0.98 [0.6,1.5]	0.92
Scenic sites					
0-3	236 (76)	73 (24)	309 (25)	—	
>3	696 (75)	230 (25)	926 (75)	1.07 [0.8,1.4]	0.67
Sport venues					
no	97 (68)	46 (32)	143 (11.6)	—	
yes	835 (76)	257 (24)	1092 (88.4)	0.65 [0.4,0.9]	0.025
Recreational areas					
no	84 (81)	20 (19)	104 (8.4)	—	
yes	848 (75)	283 (25)	1131 (91.6)	1.4 [0.8,2.3]	0.19
Food spots (median)	198 [0,2087]	216 [0,2179]	207 [0,2179]	1 [1,1]	0.27

Satisfaction towards living environment					
less satisfied	165 (73)	61 (27)	226 (18.3)	—	
more satisfied	740 (76)	231 (24)	971 (78.6)	0.85 [0.6,1.2]	0.33
unknown	27 (71)	11 (29)	38 (3.1)		
Parents' satisfaction towards living environment					
less satisfied	159 (75)	54 (25)	213 (17.2)	—	
more satisfied	710 (76)	220 (24)	930 (75.3)	0.88 [0.6,1.2]	0.46
unknown	63 (68)	29 (32)	92 (7.4)		
Total	932 (75)	303 (25)	1235		

Table 2. Study population characteristics, by Body Mass Index – normal vs overweight, Changzhou

	BMI			Univariate Analysis	
Variables	<i>Normal</i>	<i>Overweight</i>	<i>Total</i>		
	No. (%)	No. (%)	No. (%)	<i>Crude OR [95%CI]</i>	<i>P</i>
Age					
≤ 13	139 (74)	49 (26)	188 (23.6)	—	
14	420 (74)	146 (26)	566 (71)	0.99 [0.7,1.4]	0.94
15	33 (77)	10 (23)	43 (5.4)	0.86 [0.4,1.9]	0.70
Sex					
Female	326 (80)	84 (20)	410 (51.4)	—	
Male	266 (69)	121 (31)	387 (48.6)	1.77 [1.3,2.4]	0.001
<i>Dietary and Exercise factors</i>					
Medium strength activity					
≤ 30 min/d	185 (75)	62 (25)	247 (31)	—	
> 30 min/d	407 (74)	143 (26)	550 (69)	1.05 [0.7,1.5]	0.79
Sweeten food				1.03 [0.9,1.2]	0.65
never	172 (75)	57 (25)	229 (28.7)		
1-2 times/month	165 (77)	49 (23)	214 (26.9)		
1-2 times/week	147 (68)	68 (32)	215 (27)		
2-3 times/week	68 (83)	14 (17)	82 (10.3)		
every day	18 (69)	8 (31)	26 (3.3)		
unknown	22 (71)	9 (29)	31 (3.9)		
BBQ				1.1 [0.9,1.3]	0.3
never	264 (78)	76 (22)	340 (42.7)		
1-2 times/month	205 (71)	85 (29)	290 (36.4)		
1-2 times/week	69 (73)	26 (27)	95 (11.9)		
2-3 times/week	27 (82)	6 (18)	33 (4.1)		
every day	4 (57)	3 (43)	7 (0.9)		

unknown	23 (72)	9 (28)	32 (4)		
Snacks				0.97 [0.8,1.1]	0.67
never	154 (73)	57 (27)	211 (26.5)		
1-2 times/month	144 (74)	51 (26)	195 (24.5)		
1-2 times/week	154 (77)	45 (23)	199 (25)		
2-3 times/week	77 (72)	30 (28)	107 (13.4)		
every day	41 (76)	13 (24)	54 (6.8)		
unknown	22 (71)	9 (29)	31 (3.9)		
<i>Family factors</i>					
Economic status				0.89 [0.7,1.2]	0.44
lower	199 (73)	75 (27)	274 (34.4)		
medium	260 (75)	85 (25)	345 (43.3)		
higher	30 (79)	8 (21)	38 (4.8)		
unknown	103 (74)	37 (26)	140 (17.6)		
Father's BMI					
normal	315 (78)	87 (22)	402 (50.4)	—	
overweight	193 (67)	93 (33)	286 (35.9)	1.74 [1.2,2.5]	0.001
underweight	21 (88)	3 (13)	24 (3)	0.52 [0.2,1.8]	0.30
unknown	63 (74)	22 (26)	85 (10.7)	1.26 [0.7,2.2]	0.40
Mother's BMI					
normal	418 (79)	110 (21)	528 (66.2)	—	
overweight	60 (53)	54 (47)	114 (14.3)	3.42 [2.2,5.2]	<0.0001
underweight	63 (79)	17 (21)	80 (10)	1.03 [0.6,1.8]	0.932
unknown	51 (68)	24 (32)	75 (9.4)	1.79 [1.1,3]	0.031
Parents' encouragement for exercise					
less encourage	324 (75)	108 (25)	432 (54.2)	—	
more encourage	200 (72)	76 (28)	276 (34.6)	1.1 [0.8,1.6]	0.57
unknown	68 (76)	21 (24)	89 (11.2)		

Father fitness time					
less	286 (74)	102 (26)	388 (48.7)	—	
more	265 (74)	91 (26)	356 (44.7)	0.97 [0.7,1.3]	0.86
unknown	41 (77)	12 (23)	53 (6.6)		
Mother fitness time					
less	306 (74)	110 (26)	416 (52.2)	—	
more	235 (76)	75 (24)	310 (38.9)	0.91 [0.7,1.3]	0.57
unknown	51 (72)	20 (28)	71 (8.9)		
Father's history of smoking					
no	240 (75)	82 (25)	322 (55.3)	—	
yes	325 (74)	116 (26)	441 (40.4)	1.04 [0.8,1.5]	
unknown	27 (79)	7 (21)	34 (4.3)	0.76 [0.3,1.8]	0.53
Mother's history of smoking					
no	563 (74)	193 (26)	756 (0.8)	—	
yes	6 (100)	0 (0)	6 (94.9)		
unknown	23 (66)	12 (34)	35 (4.4)		
<i>Environmental factors</i>					
Bus stops					
≤ 20	189 (80)	48 (20)	237 (29.7)	—	
>20	403 (72)	157 (28)	560 (70.3)	1.53 [1.1,2.2]	0.022
Scenic sites					
0-3	43 (81)	10 (19)	53 (6.6)	—	
>3	549 (74)	195 (26)	744 (93.4)	1.53 [0.8,3.1]	0.241
Sport venues					
no	1 (100)	0 (0)	1 (0.1)	—	
yes	591 (74)	205 (26)	796 (99.9)		
Recreational areas					
no	4 (67)	2 (33)	6 (0.8)	—	

yes	588 (74)	203 (26)	791 (99.2)	0.69 [0.1,3.8]	0.67
Food spots (median)	362 [22,1068]	372 [22,1031] [22,1068]	362	1 [1,1]	0.88
Students' satisfaction towards living environment					
less satisfied	37 (64)	21 (36)	58 (7.3)	—	
more satisfied	548 (75)	180 (25)	728 (91.3)	0.59 [0.3,1]	0.06
unknown	7 (64)	4 (36)	11 (1.4)		
Parents' satisfaction towards living environment					
less satisfied	52 (74)	18 (26)	70 (8.8)	—	
more satisfied	477 (73)	173 (27)	650 (81.6)	1.04 [0.6,1.8]	0.88
unknown	63 (82)	14 (18)	77 (9.7)		
Total	592 (74)	205 (26)	797		

TABLE 3. Adjusted odds ratios for characteristics against adolescents' overweight, Nanjing

Adjusted OR – Reduced Model		
	AOR[95%CI]	P
Age		
12	—	
13	1.23 [0.9,1.8]	0.247
14	0.89 [0.6,1.3]	0.549
15	0.99 [0.6,1.6]	0.96
Sex		
females	—	
males	2.01 [1.5,2.7]	<0.0001
Sport venues		
no	—	
yes	0.64 [0.4,1]	0.037
Recreational areas		
no	—	
yes	1.42 [0.8,2.4]	0.194
Father's BMI		
normal	—	
underweight	1.01 [0.4,2.3]	0.985
overweight	1.82 [1.4,2.5]	<0.0001
Mother's BMI		
normal	—	
underweight	0.8 [0.5,1.4]	0.426
overweight	1.77 [1.2,2.6]	0.003
Economic status	0.75 [0.6,1]	0.037
BBQ	1.19 [1,1.4]	0.019
Medium strength activity		

< 30min	—	
>30min	1.36 [1,1.8]	0.031

Note: AOR: Adjusted odds ratio, P: p value at significance level of 0.05

Note: comparing with multilevel mixed-effect model, we did not observe statistically significant difference with GLM logistic regression model ($p > 0.05$, interclass correlation < 0.01)

TABLE 4. Adjusted odds ratios for characteristics against adolescents' overweight, Changzhou

Adjusted OR - Reduced model		
	AOR [95%CI]	P
Age		
≤ 13	—	
14	0.92 [0.6,1.4]	0.67
15	0.95 [0.4,2.1]	0.91
Sex		
Females	—	
Males	1.78 [1.3,2.5]	0.001
Bus stops		
≤ 20	—	
> 20	1.63 [1.1,2.4]	0.011
Mother's BMI		
Normal	—	
Underweight	1.03 [0.6,1.8]	0.93
Overweight	3.57 [2.3,5.5]	<0.0001

Note: AOR: Adjusted odds ratio, P: p value at significance level of 0.05

Note: comparing with multilevel mixed-effect model, we did not observe statistically significant difference with GLM logistic regression model ($p > 0.05$, interclass correlation < 0.01)