


RESEARCH ARTICLE

Open Access



The association between living environmental factors and adolescents' body weight: a cross-sectional study

Siyi Huang^{1,2*} , Sha Sha³, Wei Du⁴, Hanwen Zhang³, Xinyi Wu⁵, Chongmin Jiang¹, Yan Zhao⁶ and Jie Yang⁷

Abstract

Background: The effect of the 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 multivariate logistic regressions to explore potential correlations after considering a range of potential confounding factors.

Results: Approximately 25% ($n = 303$) of students from Nanjing and 26% ($n = 205$) of students from Changzhou were excessive body weight. In Nanjing, students' BMI (Body Mass Index) showed a strong negative correlation with the number of sports venues in their neighborhood (Adjusted Odds Ratio (AOR): 0.64, 95%CI: 0.40–0.94) after controlling for other covariates. In Changzhou, we observed a positive correlation between adolescents' body weight and the number of bus stops in their neighbourhood (AOR:1.63, 95%CI:1.11–2.38).

Conclusions: The living environment factors were independently associated with teenagers' excessive body weight. We hypothesis that the environmental risk factors might be associated with political management, which will consequently affect personal health outcomes. Further research and proactive measures are required to manage those potential risks and attenuate the problem.

Keywords: Excessive body weight, Living environmental factors, Adolescents

Background

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 worldwide [1]. Regretfully, over the recent three decades, little progress has been achieved in treating or preventing excessive body weight [2]. It was 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 severity of the overweight issues, [4] especially common in low-income families [5]. Traditional policymakers and doctors [4] just paid attention to the severe obesity patients, ignoring health-care costs incurred by the overweight group. There were only a few overweight patients to link their terrible

*Correspondence: 564182909@qq.com

² Department of Sport and Exercise Science, Zhejiang University, Hangzhou, China

Full list of author information is available at the end of the article



© The Author(s) 2021. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

physiological situations with their excessive BMI [4, 6]. 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 [7, 8]. The economic burden of overweight and obesity has also reached US\$2 trillion, matching that of smoking and all military conflict [9]. 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 [10, 11]. 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 [12, 13]. Pineda E et al. 2019 emphasized that the distance to the nearest fast-food restaurants elevated the risk of overweight and obesity, especially in low-income students [14]. A straightforward hypothesis is that the environmental characteristics, including the presence of cycle paths, sidewalks, active public transportation [15], green spaces [14] and the degree of urbanization, are related to childhood body weight. 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 [16–18].

Although the current research has addressed the significant relationship between environmental factors and adolescents' excessive body weight, several essential aspects have not been scrutinized, such as parents' attitudes towards students doing outdoor activities and influence from large-scale municipal works projects. Most studies on the relationship between the built environment and childhood excessive body weight, in addition, were mainly conducted in developed countries [19]. 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 healthy food or changing citizens' life behaviours [19, 20]. 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.

Considering 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 between 11 to 15 years old. These two cities have similar economic and cultural backgrounds, but Nanjing has a larger population and a more prosperous built environment setting than Changzhou. Therefore, we ran a parallel analysis for each city, respectively.

The cross-sectional survey was conducted in all districts in Changzhou and nine 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., Grade 7–9). We excluded residential students who lived in the school dormitories and those 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 2018, and this study was approved by China Institute of Sports Science ethics committee (Ethical code: CISSIRD-201604).

Study outcome

According to the latest *State Students Health Standards*, we categorized BMI of the study participants into the normal weight group and excessive body weight group (combined overweight and obesity) [21]. We excluded 182 underweight students (127 from Nanjing, 55 from Changzhou) from the analysis. We ran sensitivity analysis and did not find material change.

Study factors

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 m distance from their home address. In this research, we defined the five aspects in advance.

- (1) bus stops mean the number of bus stops.
- (2) food spots, including restaurants, cafeterias, bubble tea stores, coffee shops, and street food spots.
- (3) scenic spots covering parks, historical places, and ancient temples.
- (4) sports venues including sports facilities center, public sports playgrounds, fitness trail, and stadium.
- (5) recreation areas covering shopping centers, zoos, museums, carnies, and aquaria.

We further categorized the number of bus stops as over 20 or not, scenic sites as over three 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.

Measurements of physical activities

Based on the China health and nutrition survey questionnaire and Godin Shephard questionnaire, we designed our physical activity part in our questionnaire. The physical activity time consisted of exercise time at school, including physical education, recess, club activities, extracurricular activity time, and out of school, covering after-school interest classes, after-school playtime, and commuting time. Compendium of Energy Expenditures for Youth was used to identify the intensity of different exercises. We utilized reproducibility to check the reliability of the data. For the Moderate-to-Vigorous Physical Activities (MVPA) at school, we gained the students' schooling timetable from the educational staff. At the same time, students also reported their spending time in MVPA at school. Parents and children respectively reported spending time for exercise out of school. Reproducibility was assessed via intra-class correlation coefficients for both spending time at and out of school (Intraclass Correlation Coefficient, ICC > 0.7), so the data was considered reliable.

Measurements of diet behaviours

Due to our pilot study, it was not easy for teenagers to accurately recall the types and sizes of food they ate in 48 h. Therefore, we collected the frequency of high sweetened food or fried food in the diet aspect rather than daily energy consumption.

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, 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 excessive body weight. 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 and fried 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 (52.5%, *n* = 648 among fathers; 67.2%, *n* = 830 among mothers), 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 spots (75%, *n* = 926), with any sport venues (88.4%, *n* = 1092) and any recreational areas (91.6%, *n* = 1131) within 500-m 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.

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

Variables	BMI			Univariate Analysis	
	Normal	Excessive bodyweight	Total	Crude OR [95%CI]	P
	No. (%)	No. (%)	No. (%)		
Age					
≤ 12	232 (77)	69 (23)	301 (24.4)	–	
13	333 (72)	127 (28)	460 (37.2)	1.28 [0.91,1.8]	0.15
14	244 (79)	66 (21)	310 (25.1)	0.91 [0.62,1.33]	0.63
≥ 15	123 (75)	41 (25)	164 (13.3)	1.12 [0.72,1.75]	0.62
Sex					
Female	514 (82)	113 (18)	627 (50.8)	–	
Male	418 (69)	190 (31)	608 (49.2)	2.07 [1.58,2.7]	< 0.0001
Dietary and Exercise factors					
Moderate-to-vigorous physical activity					
≤ 30 min/d	600 (78)	172 (22)	772 (62.5)	–	
> 30 min/d	332 (72)	131 (28)	463 (37.5)	1.38 [1.06,1.79]	0.018
Sweeten food				1.02 [0.91,1.15]	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 and fried food				1.19 [1.04,1.36]	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 [0.89,1.09]	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 [0.6,0.97]	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)	1.93 [1.34,2.79]	< 0.0001
Underweight	31 (79)	8 (21)	39 (3.2)	0.78 [0.46,1.31]	0.96
Unknown	113 (75)	38 (25)	151 (12.2)		
Mother's BMI					
Normal	643 (77)	187 (23)	830 (67.2)	–	
Overweight	98 (64)	55 (36)	153 (12.4)	1.83 [1.38,2.44]	< 0.0001

Table 1 (continued)

Variables	BMI			Univariate Analysis	
	<i>Normal</i>	<i>Excessive bodyweight</i>	<i>Total</i>	<i>Crude OR [95%CI]</i>	<i>P</i>
	No. (%)	No. (%)	No. (%)		
Underweight	84 (82)	19 (18)	103 (8.3)	1.02 [0.46,2.27]	0.35
Unknown	107 (72)	42 (28)	149 (12.1)		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 [0.67,1.17]	0.38
Unknown	58 (73)	21 (27)	79 (6.4)		
Father fitness time					
Shorter	469 (76)	145 (24)	614 (49.7)	–	
Longer	273 (75)	90 (25)	363 (29.4)	1.02 [0.76,1.36]	0.92
Unknown	190 (74)	68 (26)	258 (20.9)		
Mother fitness time					
Shorter	459 (76)	146 (24)	605 (49)	–	
Longer	391 (75)	133 (25)	524 (42.4)	1.05 [0.8,1.37]	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 [1.09,1.94]	0.01
Unknown	34 (71)	14 (29)	48 (3.9)		
Mother smoking					
No	858 (76)	270 (24)	1128 (91.3)	–	
Yes	8 (67)	4 (33)	12 (1)	1.59 [0.47,5.32]	0.45
Unknown	66 (69)	29 (31)	95 (7.7)		
Satisfaction towards living environment					
Less satisfied	165 (73)	61 (27)	226 (18.3)	–	
More satisfied	740 (76)	231 (24)	971 (78.6)	0.85 [0.61,1.18]	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 [0.64,1.23]	0.46
Unknown	63 (68)	29 (32)	92 (7.4)		
Environmental factors					
Bus stops					
≤ 20	88 (76)	28 (24)	116 (9.4)	–	
> 20	844 (75)	275 (25)	1119 (90.6)	0.98 [0.62,1.53]	0.92
Scenic spots					
0–3	236 (76)	73 (24)	309 (25)	–	
> 3	696 (75)	230 (25)	926 (75)	1.07 [0.79,1.44]	0.67
Sport venues					
No	97 (68)	46 (32)	143 (11.6)	–	
Yes	835 (76)	257 (24)	1092 (88.4)	0.65 [0.44,0.95]	0.025
Casual spots					
No	84 (81)	20 (19)	104 (8.4)	–	
Yes	848 (75)	283 (25)	1131 (91.6)	1.4 [0.85,2.32]	0.19
Food spots (median)	198 [0,2087]	216 [0,2179]	207 [0,2179]	1 [1,1]	0.27
Total	932 (75)	303 (25)	1235		

OR Odds ratio, *p* *p*-value

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

Variables	BMI			Univariate Analysis	
	Normal	Excessive bodyweight	Total	Crude OR [95%CI]	P
	No. (%)	No. (%)	No. (%)		
Age					
≤ 13	139 (74)	49 (26)	188 (23.6)	–	
14	420 (74)	146 (26)	566 (71)	0.99 [0.68,1.44]	0.94
≥ 15	33 (77)	10 (23)	43 (5.4)	0.86 [0.39,1.87]	0.70
Sex					
Female	326 (80)	84 (20)	410 (51.4)	–	
Male	266 (69)	121 (31)	387 (48.6)	1.77 [1.28,2.44]	0.001
Dietary and Exercise factors					
Moderate-to-vigorous physical activity					
≤ 30 min/d	185 (75)	62 (25)	247 (31)	–	
> 30 min/d	407 (74)	143 (26)	550 (69)	1.05 [0.74,1.48]	0.79
Sweeten food				1.03 [0.89,1.2]	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 and fried food				1.1 [0.92,1.32]	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 [0.85,1.11]	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)		
Family factors					
Economic status				0.89 [0.67,1.19]	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 [1.24,2.46]	0.001
Underweight	21 (88)	3 (13)	24 (3)	0.52 [0.15,1.77]	0.30
Unknown	63 (74)	22 (26)	85 (10.7)		
Mother's BMI					
Normal	418 (79)	110 (21)	528 (66.2)	–	
Overweight	60 (53)	54 (47)	114 (14.3)	3.42 [2.24,5.22]	< 0.0001
Underweight	63 (79)	17 (21)	80 (10)	1.03 [0.58,1.82]	0.932

Table 2 (continued)

Variables	BMI			Univariate Analysis	
	<i>Normal</i>	<i>Excessive bodyweight</i>	<i>Total</i>	<i>Crude OR [95%CI]</i>	<i>P</i>
	No. (%)	No. (%)	No. (%)		
Unknown	51 (68)	24 (32)	75 (9.4)		
Parents' encouragement for exercise					
Less encourage	324 (75)	108 (25)	432 (54.2)	–	
More encourage	200 (72)	76 (28)	276 (34.6)	1.1 [0.79,1.55]	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 [0.7,1.35]	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 [0.65,1.26]	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 [0.75,1.45]	0.79
Unknown	27 (79)	7 (21)	34 (4.3)		
Mother's history of smoking					
No	563 (74)	193 (26)	756 (0.8)	–	
Yes	6 (100)	0 (0)	6 (94.9)	N/A	
Unknown	23 (66)	12 (34)	35 (4.4)		
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 [0.34,1.03]	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)		
Environmental factors					
Bus stops					
≤ 20	189 (80)	48 (20)	237 (29.7)	–	
> 20	403 (72)	157 (28)	560 (70.3)	1.53 [1.06,2.21]	0.022
Scenic spots					
0–3	43 (81)	10 (19)	53 (6.6)	–	
> 3	549 (74)	195 (26)	744 (93.4)	1.53 [0.75,3.1]	0.241
Sport venues					
No	1 (100)	0 (0)	1 (0.1)	–	
Yes	591 (74)	205 (26)	796 (99.9)	N/A	
Casual spots					
No	4 (67)	2 (33)	6 (0.8)	–	
Yes	588 (74)	203 (26)	791 (99.2)	0.69 [0.13,3.8]	0.67
Food spots (median)	362 [22,1068]	372 [22,1031]	362 [22,1068]	1 [1,1]	0.88
Total	592 (74)	205 (26)	797		

OR Odds ratio, *p* *p*-value

Compared with students residing in a place without any sports venues, those who had access to sports venues near their residential places are less likely to gain excessive body weight (AOR: 0.64, 95%CI: 0.40–0.94, $P=0.027$), after controlling for other factors (Table 3). In addition to the sport venues, male students (AOR: 2.01, 95%CI: 1.49–2.71, $P<0.0001$), those having an excessive BMI parent (AOR: 1.87, 95%CI: 1.38–2.52, $P<0.0001$ for father; AOR: 1.78, 95%CI: 1.20–2.62, $P=0.004$ for mother), from lower socioeconomic background (AOR: 0.70, 95%CI: 0.52–0.94, $P=0.017$), having higher frequency of barbeque and fried food consumption (AOR: 1.18, 95%CI: 1.01–1.38, $P=0.037$), and having medium strength activity of longer than 30 min (AOR: 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 spots (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 1068.

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-m 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 (intraclass correlation <0.01 , $P>0.05$). In Table 4, we also observed a positive correlation between adolescents’ body weight and the number of bus stops in their neighbourhood (AOR:1.63, 95%CI:1.11–2.38).

Discussion

In this geographically diverse sampling of adolescents from junior high schools, our results illustrated consistent evidence that closing to a sports venue and numbers of near bus stops were independently correlated with adolescents’ body weight. To be specific, the number of bus stops put a negative impact on the prevention of the excess body weight among Changzhou students, while the high availability of sports venues created a positive

Table 3 Adjusted odds ratios for characteristics against adolescents’ overweight, Nanjing – Results from Reduced Model

Adjusted OR – Reduced Model		
	AOR	P
Age		
≤ 12	–	
13	1.30 [0.88,1.93]	0.193
14	0.93 [0.61,1.44]	0.749
15	1.04 [0.61,1.78]	0.877
Sex		
Females	–	
Males	2.01 [1.49,2.71]	<0.0001
Sport venues		
No	–	
Yes	0.61 [0.40,0.94]	0.027
Father’s BMI		
Normal	–	
Underweight	0.94 [0.39,2.23]	0.882
Overweight	1.87 [1.38,2.52]	<0.0001
Mother’s BMI		
Normal	–	
Underweight	0.89 [0.51,1.54]	0.672
Overweight	1.78 [1.20,2.62]	0.004
Economic status	0.70 [0.52,0.94]	0.017
BBQ & Fried food	1.18 [1.01,1.38]	0.037
Moderate-to-vigorous physical activity		
≤ 30 min	–	
> 30 min	1.40 [1.04,1.90]	0.025

AOR Adjusted odds ratio, p p -value

Table 4 Adjusted odds ratios for characteristics against adolescents’ overweight, Changzhou– Results from Reduced Model

Adjusted OR - Reduced model		
	OR [95%CI]	P
Age		
≤ 13	–	
14	0.92 [0.62,1.36]	0.67
15	0.95 [0.42,2.11]	0.91
Sex		
Females	–	
Males	1.78 [1.27,2.48]	0.001
Bus		
≤ 20	–	
> 20	1.63 [1.11,2.38]	0.011
Mother’s BMI		
Normal	–	
Underweight	1.03 [0.57,1.84]	0.93
Overweight	3.57 [2.32, 5.50]	<0.0001

AOR Adjusted odds ratio, p p -value

effect for Nanjing students, which was in line with the development of city policies and guidelines years [22]. 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 and enhancing the sports culture. After the Game, its heritage was transferred for public activities, and the culture prevailed [23]. According to the 2016 government report, additional efforts would be invested to mend fitness trails to grow from 420 km to 863 km, provide 691 playgrounds, and establish 341 sports facilities during the period from 2017 to 2035 [23]. 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 [24]. However, our findings were contrary to the previous results that more number of bus stops would lead to a high prevalence of childhood excessive body weight [25]. The convenient public transportation system did not show a positive impact on individuals' travelling 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 [26]. This implies that decisive policies can reverse the upwards trend of excessive body weight by modifying civil planning and access to facilities, especially for vulnerable younger children with constrained resources [27]. The young excessive body weight relates to merely eating and exercising habits and encompasses essential aspects of social and environmental situations, which might exacerbate their health outcomes and inequity [27, 28]. 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 sufficient to offer extra opportunities for adolescents to attain the unstructured exercise during their off-school time [29]. 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 [30].

It is noteworthy that the Changzhou subway project was conducted in 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 the traffic system, and the long period of metro

construction would bring numerous environmental and social issues for this city [31]. Usually, subway lines have coincided with the urban traffic-intensive hubs. It was inevitable that the construction enclosure occupied the parts of the crossroad and motorway and damaged some traffic lights, decreasing the surrounding safety [32]. Subway construction posed a substantial 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 behaviours towards more active lifestyles, with the implication of more likely to be excessive body weight [32]. 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 [33]. 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 BMI, family income, being male, and barbecue food consumption, were associated with young adolescents' excessive body weight, consistent with previous findings [14, 34–36]. For example, genetic factors influenced fat distribution as well as daily energy expenditure, energy intake, and habitual physical activities [14]. It is also speculated that families with higher incomes could have more access to healthy food and live healthier lifestyles [37]. However, the lack of comparable exposure data limited our ability to confirm such relationships. Besides, there was a positive correlation between moderate physical activity and gaining excessive body weight in our project. Previous reports have demonstrated that acute aerobic exercise could generate a short-term energy deficit, disturbing the personal energy balance and contributing to a biological inevitability post-exercise compensatory eating and energy intake [38, 39]. It was noticed that the extent of compensation could be different among individuals [40]. To some populations, the compensatory adjustment might increase individual energy intake, but some could not. Whereas, considering the financial budget and operationalization of the experiment, we did not collect the information on the daily food types and sizes that students ate, which need further exploration.

Excessive body weight in school-aged children in China remains a public health issue. Further efforts to reduce childhood excessive body weight are warranted [41]. 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 concerning childhood excessive body weight.

Strength and limitations

This cross-sectional study assessed the environmental factors of excessive body weight with descriptive data and a relatively sizeable random sample comprising 1362 students from Nanjing and 826 from Changzhou. Our study compared two cities located on the southeast coast of China: Nanjing and Changzhou. Both cities are equipped with a similar economic and cultural background but differ significantly in political status, which resulted in differences in policy implementation. Nanjing is the capital city of Jiangsu province, so the annual financial expenditure and policy implementation will be skewed towards it. For the first time, we found the potential impacts of policy decisions on local adolescents' body weight.

What is more, we also boldly attempted to incorporate obese and overweight individuals into the excessive body weight group to avoid underestimating the severity of the overweight group. The high level of BMI has already brought a significant burden on their family and society. We thus have to understand that the purpose of our interventions was to decrease the mean of BMI the whole excessive body weight rather than decline the number of the severely obese population [4].

However, this cross-sectional study suffers several limitations, including the lack of crime data (for security reasons, we did not gain the data from police departments) concerning young adolescents' residential areas. We consequently were not able to explore whether satisfaction with neighbourhood safety would impact young adolescents' physical activities [42]. Besides, financially we did not utilise the ActiGraph GT3X-BT accelerometer to collect participants' daily energy consumption data. The inaccuracy of total diet energy intake by the self-report was documented in the former researches, and the accuracy of energy intake did not meet our requirements in our pilot study [43]. We, therefore, chose the alternative variables, such as the frequency of sweetening food and high-fat food. Moreover, the nature of cross-sectional data limits the cause-effect inference because we assessed the exposure and outcomes simultaneously, and it was difficult for us to tell whether the outcome followed exposure in time. Further qualitative research is needed to explore the motivations and hidden reasons for personal behaviours.

Conclusions

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 that teenagers' excessive body weight is still a significant health concern, further research and proactive measures are required to attenuate the problem.

Abbreviations

AOR: Adjusted Odds Ratio; BMI: Body Mass Index; ICC: Intraclass Correlation Coefficient; MVPA: Moderate-to-Vigorous Physical Activities; OR: Odds Ratio.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12887-021-03054-8>.

Additional file 1.

Acknowledgements

The data collecting tasks received support from Changzhou and Nanjing education departments and local secondary schools. All authors made contributions to each part of the project, participated in project designing, helped to analyze the data, and guided me to modify the final essay.

Authors' contributions

All authors provided critical input and approved the final version. WD, SH and HZ were responsible for the study design and data collecting. SS conducted data analysis and interpretation. SH and XW finished the literature review aspects. Based on the suggestion from WD, SH, SS and XW wrote the first draft of this manuscript. CJ, YZ, and JY provided the critical revision of the manuscript for important intellectual content.

Funding

This project was mainly funded by China Institute of Sports Science (CISS), numbers: Basic Research Funds 17-44,18-27,19-04. WD is supported by the Department of Education (No.1125000172) and Fundamental Research Funds for the Central Universities (No.3225002002A1). The funding source was not involved in the study design, collection, analysis, or interpretation of data. Writing of the report, and/or decision to submit the article for publication, was not affected by the funder.

Availability of data and materials

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

Declarations

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.

Consent for publication

Not Applicable.

Competing interests

No competing financial interests exist.

Author details

¹Youth Sport Research & Development Center, China Institute of Sport Science, Beijing, China. ²Department of Sport and Exercise Science, Zhejiang University, Hangzhou, China. ³Australian National University College of Medicine Biology and Environment, Canberra, Australia. ⁴Key Laboratory

of Environmental Medicine Engineering, Ministry of Education; School of Public Health, Southeast University, Nanjing, China. ⁵The First Affiliated Hospital, Sun Yat-sen University, Guangzhou, China. ⁶School of Sports and Health, Nanjing Sport Institute, Nanjing, China. ⁷Jiangsu Province CDC: Jiangsu Province Center for Disease Control and Prevention, Nanjing, China.

Received: 4 October 2020 Accepted: 5 December 2021

Published online: 13 December 2021

References

- WHO: New global estimates of child and adolescent obesity released on World Obesity Day. 2017. <https://www.who.int/end-childhood-obesity/news/new-estimate-child-adolescent-obesity/en/>. Accessed 31 May 2020.
- Kleinert S, Horton R. Rethinking and reframing obesity. *Lancet*. 2015;385:2326–8.
- Ma G. China obesity report. 2017. <http://archive.unicef.cn/cn/uploadfile/2018/0423/20180423105630638.pdf>. Accessed 31 May 2020.
- James WPT, McPherson K. The costs of overweight. *Lancet Public Health*. 2017;2:e203–e4.
- West DS, Raczynski JM, Phillips MM, Bursac Z, Gauss CH, Montgomery BEE. Parental Recognition of Overweight in School-age Children. *Obesity* (Silver Spring, Md.). 2008;16:630–6.
- Robinson E. Overweight but unseen: a review of the underestimation of weight status and a visual normalization theory. *Obes Rev*. 2017;18:1200–9.
- Li D-K, Chen H, Ferber J, Odouli R. Infection and antibiotic use in infancy and risk of childhood obesity: a longitudinal birth cohort study. *Lancet Diabetes Endocrinol*. 2016;5:18–25.
- Jaacks LM, Vandevijvere S, Pan A, McGowan CJ, Wallace C, Imamura F, et al. The obesity transition: stages of the global epidemic. *Lancet Diabetes Endocrinol*. 2019;7:231–40.
- Dobbs R, Sawers C, Thompson F, Manyika J, Woetzel J, Child P. Overcoming obesity: an initial economic assessment. In: A discussion paper by the McKinsey Global Institute; 2014. https://www.mckinsey.com/~media/McKinsey/Business%20Functions/Economic%20Studies%20TEMP/Our%20Insights/How%20the%20World%20Could%20better%20fight%20obesity/MGI_Overcoming_obesity_Executive_summary.pdf. Accessed 31 May 2020.
- Pelusi C, Altieri P, Gambineri A, Repaci A, Cavazza C, Fanelli F, et al. Behavioral, socio-environmental, educational and demographic correlates of excess body weight in Italian adolescents and young adults. *Nutr Metab Cardiovasc Dis*. 2018;29:279–89.
- Spilkova J. Teenage overweight and obesity: a pilot study of obesogenic and obesoprotective environments in the Czech Republic. *Morav Geogr Rep*. 2016;24:55–64.
- Villanueva R, Albaladejo R, Astasio P, Ortega P, Santos J, Regidor E. Socio-economic environment, area facilities and obesity and physical inactivity among children. *Eur J Public Health*. 2015;26:267–71.
- Xu F, Chepyator-Thomson J, Liu W, Schmidlein R. Association between social and environmental factors and physical activity opportunities in middle schools. *Eur Phys Educ Rev*. 2010;16:183–94.
- Pineda E, Swinburn B, Sassi F. Effective school food environment interventions for the prevention of childhood obesity: systematic review and meta-analysis. *Lancet*. 2019;394:577.
- Wen LM, Rissel C. Inverse associations between cycling to work, public transport, and overweight and obesity: findings from a population based study in Australia. *Prev Med*. 2008;46:29–32.
- Evans GW, Jones-Rounds ML, Belojevic G, Vermeylen F. Family income and childhood obesity in eight European cities: the mediating roles of neighborhood characteristics and physical activity. *Soc Sci Med*. 2012;75:477–81.
- Carson V, Kuhle S, Spence JC, Veugeleers PJ. Parents' perception of neighbourhood environment as a determinant of screen time, physical activity and active transport. *Can J Public Health*. 2010;101:124–7.
- Veitch J, Timperio A, Crawford D, Abbott G, Giles-Corti B, Salmon J. Is the neighbourhood environment associated with sedentary behaviour outside of school hours among children? *Ann Behav Med*. 2011;41:333–41.
- An R, Shen J, Yang Q, Yang Y. Impact of built environment on physical activity and obesity among children and adolescents in China: a narrative systematic review. *J Sport Health Sci*. 2019;8:153–69.
- 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 Nutr*. 2012;15:88–96.
- The Ministry of Education of the People's Republic of China. Student Physical Health Standard. 2014. https://zb.swufe.edu.cn/_local/3/87/96/2A684F6BDCBAA9F5E81D3400770_9BE7D81F_18D804.pdf. Accessed 31 May 2020.
- Malik VS, Willett WC, Hu FB. Global obesity: trends, risk factors and policy implications. *Nat Rev Endocrinol*. 2012;9:13–27.
- Nanjing Government: "Nanjing City Sports Facilities Special Plan" released in 2035, there will be 1 football field for every 10,000 people. 2019. http://www.nanjing.gov.cn/mszx/201908/t20190802_1615473.html. Accessed 31 May 2020.
- People's Daily: Daily passenger capacity of Changzhou BRT reached 300,000 person-times. 2015. <http://js.people.com.cn/n/2015/1204/c360302-27249305.html>. Accessed 31 May 2020.
- Chen C, Menifield CE. An ecological study on means of transportation to work and obesity: evidence from US states. *Transp Policy*. 2017;59:174–80.
- Mendenhall E. Syndemics: a new path for global health research. *Lancet*. 2017;389:889–91.
- Giles-Corti B, Vernez-Moudon A, Reis R, Turrell G, Dannenberg AL, Badland H, et al. City planning and population health: a global challenge. *Lancet*. 2016;388:2912–24.
- Voss L, Hosking J, Metcalf B, Jeffery A, Wilkin T. 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 Dev*. 2008;34:470–4.
- Floyd MF, Bocarro JN, Smith WR, Baran PK, Moore RC, Cosco NG, et al. Park-based physical activity among children and adolescents. *Am J Prev Med*. 2011;41:258–65.
- Chen P, Wang D, Shen H, Yu L, Gao Q, Mao L, et al. Physical activity and health in Chinese children and adolescents: expert consensus statement (2020). *Br J Sports Med*. 2020;0:1–11.
- Huabo NIE. The impact of Subway construction on urban traffic. *J Transp Inform Safety*. 2011;29(6):65–72. <https://doi.org/10.3963/JISSN16744861.2011.06.015>, https://en.cnki.com.cn/Article_en/CJFDTotal-JTJS201106016.htm.
- Xue X, Zhang R, Zhang X, Yang RJ, Li H. Environmental and social challenges for urban subway construction: An empirical study in China. *Int J Proj Manag*. 2015;33:576–88.
- Eastday: Automobile ownership of prefecture-level cities in Jiangsu in 2018. 2020. <https://mini.eastday.com/a/200121025319835.html>. Accessed 31 May 2020.
- 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. *Obes Rev*. 2011;12:e130–e42.
- Meng X-R, Song J-Y, Ma J, Liu F-H, Shang X-R, Guo X-J, et al. Association study of childhood obesity with eight genetic variants recently identified by genome-wide association studies. *Pediatr Res*. 2014;76:310–5.
- Carroll-Scott A, Gilstad-Hayden K, Rosenthal L, Peters SM, McCaslin C, Joyce R, et al. Disentangling neighborhood contextual associations with child body mass index, diet, and physical activity: the role of built, socioeconomic, and social environments. *Soc Sci Med*. 2013;95:106–14.
- Singh GK, Siahpush M, Kogan MD. Neighborhood socioeconomic conditions, built environments, and childhood obesity. *Health Aff*. 2010;29:503–12.
- Finlayson G, Bryant E, Blundell JE, King NA. Acute compensatory eating following exercise is associated with implicit hedonic wanting for food. *Physiol Behav*. 2009;97:62–7.
- King NA, Caudwell P, Hopkins M, Byrne NM, Colley R, Hills AP, et al. Metabolic and Behavioral Compensatory Responses to Exercise Interventions: Barriers to Weight Loss. *Obesity* (Silver Spring, Md.). 2007;15:1373–83.
- Hopkins M, Blundell JE, King NA. Individual variability in compensatory eating following acute exercise in overweight and obese women. *Br J Sports Med*. 2014;48:1472–6.
- Gortmaker SL, Swinburn BA, Levy D, Carter R, Mabry PL, Finegood DT, et al. Changing the future of obesity: science, policy, and action. *Lancet*. 2011;378:838–47.
- Creator MI, Glazier RH, Moineddin R, Fazli GS, Johns A, Gozdyra P, et al. Association of neighborhood walkability with change in overweight, obesity, and diabetes. *JAMA*. 2016;315:2211–20.

43. Schoeller DA. How accurate is self-reported dietary energy intake? *Nutr Rev.* 2009;48:373–9.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Ready to submit your research? Choose BMC and benefit from:

- fast, convenient online submission
- thorough peer review by experienced researchers in your field
- rapid publication on acceptance
- support for research data, including large and complex data types
- gold Open Access which fosters wider collaboration and increased citations
- maximum visibility for your research: over 100M website views per year

At BMC, research is always in progress.

Learn more biomedcentral.com/submissions

