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Original Research Article

Synthesis May Be Better than Singleness— A Cross-sectional Study on Physical Activity Environment, Food Environment and Adolescents' BMI

Li Lu[1*]

[1]Department of Physical Education and Health Science, Zhejiang Normal, University.NO.688, Yingbing Road, Wucheng District, Jinhua City, Zhejiang Province, China

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***Corresponding author:** Li Lu
Department of Physical Education and Health Science, Zhejiang Normal, University.NO.688, Yingbing Road, Wucheng District, Jinhua City, Zhejiang Province, China

Abstract

***Objectives*:** To analyze the relationship between residential physical activity environment and food environment respectively and adolescent BMI level, the correlation between adolescent physical activity level and food intake behavior respectively and adolescent BMI level, as well as compare the difference of correlation between residential single physical activity environment or combined physical activity environment and adolescent BMI level, and the difference of correlation between food environment and adolescent BMI level. ***Methods*:** Based on the cross-sectional study design, a total of 1035 adolescents aged 11 to 17 years were surveyed in the urban area of Jinhua City. The final valid sample was 884 (including 411 males and 473 females) after screening, due to the methodological difficulties of the food intake frequency survey. The height and weight of the sample were measured, and the subjective perception evaluation of physical activity level, frequency of food intake, residential physical activity environment, and food environment were investigated. ***Results*:** (1) No significant difference exists in BMI between physical activity levels in the sample overall and among men, but a significant difference exists between physical activity levels among women ($p<0.05$). A significant difference exists in BMI between the frequencies of non-healthy food intake in the overall sample ($p<0.05$ or $p<0.01$). After differentiating by gender, there were significant differences in BMI among different frequencies of fried food, puffed food, and carbonated beverage intake among men ($p<0.05$ or $p<0.01$), and among women for different frequencies of puffed food, sugary drinks, and carbonated beverages ($p<0.05$ or $p<0.01$). (2) All indicators of physical activity environment in the residence were correlated with the physical activity level of adolescents and were significant ($p<0.05$ or $p<0.01$). The physical activity level of females compared to males was correlated with the safety of physical activity facilities and other environmental indicators in and around the residence and was significant after differentiating by gender. (3) Binary Logistic Regression results showed that when the independent variable was the combination of "physical activity and frequency of food intake", fried food (OR=1.771, $p<0.05$), puffed food (OR=1.762, $p<0.05$), and carbonated beverage intake frequency (OR=2.082, $p<0.05$) were risk factors for adolescent obesity. When the independent variable was a combination of "physical activity environment and food environment", fewer stray dogs roaming in and around the residence (OR=0.766, $p<0.05$), better physical activity venues/facilities (OR=0.661, $p<0.05$), and more free physical exercise areas (OR= 0.686, $p < 0.01$) were protective factors for adolescent obesity. ***Conclusion*:** The overall physical activity level of adolescents in Jinhua urban area was low and the frequency of unhealthy food intake was high. The differences between groups with different unhealthy food intake frequencies were significant. There were significant correlations between physical activity environment and physical activity level of adolescents, and food environment and frequency of unhealthy food intake of adolescents. A better physical activity environment and food environment in and around the residence contributed to adolescents showing relatively lower BMI levels. Female adolescents need to pay more attention to the combined effect of "physical activity environment and food environment" in obesity prevention and control, compared with male adolescents.

Keywords: physical activity environment; food environment; physical activity; adolescent obesity.

1. INTRODUCTION

Obesity rates among adolescents have been increasing at a worrying rate globally over the past three decades, from 10.2% to 22.6% among male and female adolescents in developed countries, and from 8.4% to 13.4% among male and female adolescents in developing countries, respectively, between 1980 and 2013 (Black and Macinko, 2010; Ng *et al*., 2014). The detection rate of obesity among Chinese adolescents was low in the 1980s, and since the 1990s, the problem of obesity among Chinese urban adolescents has also

become increasingly serious (Dong *et al*., 2016). The 2014 obesity detection rates in China were 11% for males and 5.8% for females aged 7-18 years in urban areas (Sun *et al*., 2014), showing that the increase in adolescent obesity has become a prominent public health problem in China and other countries. Adolescent obesity is an important predictor of adult obesity, and more than 60% of adolescents who are obese before puberty are also obese in early adulthood (Deshmukh-Taskar *et al*., 2006). Obesity poses a serious health risk with its increased risk of chronic diseases such as diabetes and cardiovascular disease (Spruijt-Metz, 2011; Bruyndonckx *et al*., 2016) and may lead to lower academic performance and self-esteem in adolescents (Cummings *et al*., 2022). Therefore, preventing and controlling the rate of obesity in adolescents is important.

Obesity is primarily characterized by an excess of energy intake over energy expenditure, which in turn is primarily derived from physical activity, but the etiology of obesity is often complex and multifactorial. Genetic biology and psychology at the individual level cannot explain the rapid increase in obesity rates in the short term. Based on the development of socio-ecological theoretical modeling, researchers have begun to try explaining obesity in the context of broader environmental and social changes (Sallis and Glanz, 2009). With the advancement of urbanization in recent years, the sprawl of urban space and motorization of traffic have followed, and urban development in China has faced a series of problems such as high population density, housing tension, food safety, and traffic congestion, as well as a fundamental shift in people's eating habits and traffic and travel patterns. Therefore, at this stage, the prevention and control of obesity among adolescents can start from improving the environment and healthy physical behavior.

Previous international empirical research on adolescent obesity has focused much attention on the effects of physical environmental factors of human habitation on obesity, which may be detrimental to physical activity and a healthy diet, increasing the body's energy intake and decreasing energy expenditure, which leads to obesity. Related studies have shown that living in communities with further supportive environmental features (e.g., walkability, accessibility to recreational areas, aesthetic design) is associated with higher levels of physical activity and lower BMI levels (Coogan *et al*., 2009; Gomez *et al*., 2010; Duncan *et al*., 2010). The accessibility of healthy food in settlements is associated with eating behavior and weight status (Franco *et al*., 2009; Li *et al*., 2009; Moore *et al*., 2009). Therefore, improving the quality of the food environment and physical activity environment in and around settlements may help to reduce the risk of obesity associated with unhealthy eating behaviors and physical inactivity. However, from the available reported literature, international attention with this issue is not yet high, while the retrieved literature is dominated by a small number of review-type and empirical studies (Sallis and Glanz, 2009; Han *et al*., 2022). Some studies began to try to explore the relationship between physical activity environment and physical activity level or obesity status (Laska *et al*., 2010; Wang *et al*., 2017), but the environmental elements were considered singularly, thus relatively ignoring the food environment, food intake, and other elements, while a few studies integrating the relationship between physical activity environment and food environment, related behaviors and weight status have been reported. This study takes Jinhua, Zhejiang Province, as a case urban area, and tries to investigate the issues related to food intake, physical activity and weight status from the perspective of physical activity environment and food environment in and around the residential area. This study can not only provide some reference for alleviating the epidemic trend of obesity among Chinese adolescents, but also help in providing a preliminary theoretical basis and reference value for the future development of this research field internationally.

2. METHODS

2.1 Samples

Calculations were performed using G*Power 3.1 software, the z-value test was selected, and statistical method was logistic regression analysis with a two-sided test for significance. Referring to previous cross-sectional survey studies of physical activity environment and food environment (Casey *et al*., 2012; Ohri-Vachaspati *et al*., 2013), the relevant parameters included an OR of 1.3, alpha error of 0.05, and efficacy value of 0.95, while the final calculated effective sample size was 800, and the actual efficacy value was 0.9501. 1035 adolescents aged 11-17 years were finally surveyed in this study, and the final valid sample included after screening was 884 (including 411 males and 473 females).

2.2 Questionnaire survey

(1) Demographic sociology

The demographic sociology collected the subjects' personal and family basic information. The basic personal information included gender, age, height, weight, family type, whether they were an only child, primary caregiver, and individual preferences (sports preference and fruit and vegetable preference), and the investigators compared and confirmed the data of the students' self-completed height and weight with the school physical health test data. Basic family information comprised the parents' height, weight, education level, occupation, total monthly household income, whether they smoked or drank, parents' awareness of exercise and fruits and vegetables, and awareness of the importance of exercise and healthy eating for their children. The details are shown in Appendix I.

(2) Physical activity level

The Physical Activity Questionnaire for Children and Adolescents (PAQ-CN) (Craig *et al*., 2003; Wall *et al*., 2012) was used to assess the physical activity level of a group of children and adolescents. The questionnaire was tested to have good reliability and validity, and it can reflect the physical activity level of Chinese adolescents in the survey of physical activity level of primary and secondary school students better. The main body of the questionnaire contains a total of 10 questions to judge the physical activity level of children and adolescents by reviewing their physical activity in the past week, which can be classified into low physical activity level (PAQ ≤ 2), medium physical activity level (2 < PAQ ≤ 3), and high physical activity level (PAQ > 3) according to the classification criteria of PAQ. p1 is a survey of regular activities, which is used to investigate the adolescents' past week; P2-P8 is to investigate the physical activity performance in physical education, recess, lunch break, after school, evening and weekend; P9 is to investigate the frequency of physical activity of 30 minutes or more per day in the past week; P10 is a screening question to investigate whether the normal physical activity behavior was affected by illness or special circumstances in the past week. The questionnaire uses a five-point scale, and the details are shown in Appendix II.

(3) Food intake frequency

The Food Frequency Questionnaire (FFQ) (Somaraki *et al*., 2018; Harris *et al*., 2019) was used to investigate the food intake frequency of children and adolescents aged 6-17 years in China, which was established for children and adolescents aged six to 17 years in China, including 11 categories and 72 types of food FFQ, which can accurately assess the eating habits and dietary patterns of different individuals, and this questionnaire was tested to have good reliability. This study investigated the food intake of adolescents to understand the frequency of adolescents' intake of specific types of foods, rather than attempting to quantify their food intake. The data obtained from this questionnaire will be used to assess the frequency of intake of "unhealthy foods" and "healthy foods", including fried food, puffed food, candy, iced food, and other food. Unhealthy food" includes fried food, puffed food, candy, ice cream, sugary drinks, carbonated drinks, with 6 categories. The "healthy foods" included vegetables and fruits, with two major categories. The food intake frequency was assessed by converting the food intake frequency of adolescents into the average weekly intake frequency, and then classified into frequent (≥3 times/week), occasional (>0 and <3 times/week), and never (0 times/week) according to the weekly intake frequency of each food group. The details are shown in Appendix III.

(4) Physical activity environment and food environment

This study used the Comprehensive Assessment of Physical Activity and Food Environment Scale for Urban Adolescents (Craig *et al*., 2003; Lee *et al*., 2011), to measure the physical activity environment and food environment of children and adolescents, which was developed for the Chinese adolescent population and can provide a subjective perception measurement tool for studies related to environmental factors of obesity in the adolescent population, and was tested to have good reliability and validity for the Chinese urban adolescent population It has been tested to have good reliability and validity and is suitable for research on urban adolescents in China. The physical activity and food environment scales consist of 27 questions in total. The physical activity environment consists of five dimensions: convenience of activity places, safety of activity places, sex of activity places, information and promotion of physical activities, and restrictions on the use of activity facilities; the food environment comprises three dimensions: unhealthy food, healthy food, and information and promotion of healthy eating. The sample needs to score each topic according to the actual situation, using a five-point scoring method, where higher scores for physical activity environment and food environment indicate better quality of physical activity environment and food environment in and around the settlement. The details are shown in Appendix IV.

2.3 Statistical methods

The data were imported into SPSS 22.0 for statistical processing. A descriptive statistical analysis was performed using percentages or means ± standard deviations for demographic sociological variables, covariates, BMI levels, physical activity levels, and food intake frequency check data. One-way ANOVAs were performed for various physical activity levels and BMI levels of adolescents, and different food intake frequencies and BMI levels of adolescents. Spearman analysis was used to analyze the correlations between physical activity environment and physical activity level, food environment, and food intake frequency. A dichotomous logistic analysis was conducted to determine the correlation between obesity and single physical activity level, single food intake frequency and combined "physical activity level and food intake frequency," as well as between obesity and single physical activity environment, single food environment and combined "physical activity environment and food environment". and food environment." The models were adjusted for relevant control variables, while significant influences were determined based on OR values and significance levels of p values.

3. Survey process

A multi-stage stratified whole-group sampling method was used. Wucheng District and Jindong District of Jinhua City were selected in the first stage;

the fourth middle school, the fifth middle school, the eighth middle school, the fourteenth middle school, the youth middle school, Zhejiang Trade School, and Binhong Senior High School were selected in the first stage, and considering that the age of students in the sixth grade of elementary school is generally 11 to 12 years old, an elementary school, namely, Dongyuan Primary School, was added. For the selected junior and senior high schools, one class was randomly selected for each grade, while for elementary schools, two classes were randomly selected in the sixth grade, and 45 students were randomly selected from each class selected, with an even sampling of males and females, for a total of 1035 completed samplings.

The questionnaires were prepared in advance according to the actual needs, and the teachers of each school were then contacted. The main content was to explain the purpose and significance of the study, followed by the content of the questionnaire, and finally to remind them of the issues that needed attention during the distribution process. When the questionnaires were actually distributed, the researcher followed the teachers to supervise the students to fill them out. The specific requirements are as follows: (1) emphasize that the test is not related to study or examination, and fill it out carefully according to the actual situation; (2) provide students with enough time to fill out the questionnaire to ensure the quality of filling it out; (3) consider the students' comprehension ability, and explain carefully the topics that are easy to be misunderstood and confused by students.

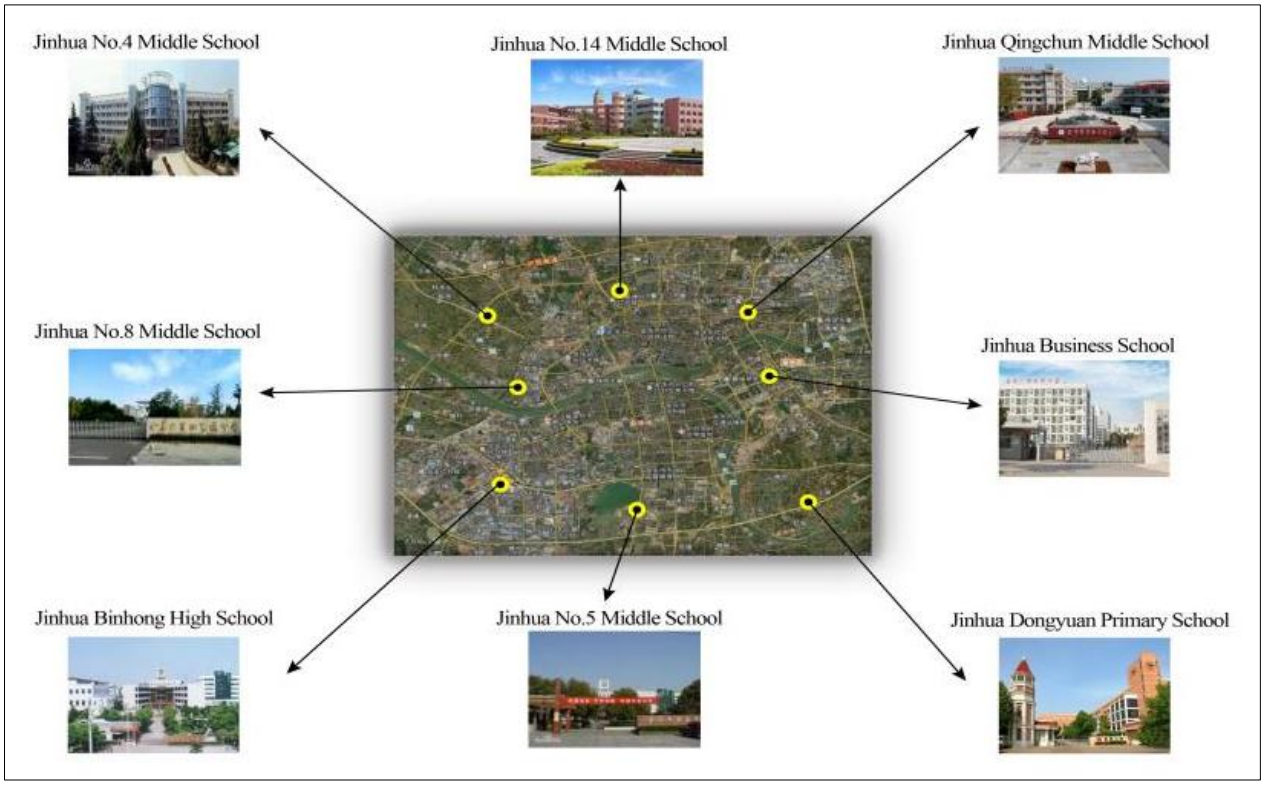

Fig-1

4. RESULTS

4.1 Physical activity level, BMI level and food intake frequency of adolescents

The physical activity level and weight characteristics of adolescent boys and girls are shown in Table 1. 46.4% and 37.6% from the overall sample were distributed in the medium and low physical activity levels, respectively, and only 15.8% were distributed in the high physical activity level. Of these, 51.8% and 22.6% were at medium and high physical activity levels, respectively, for males, and 42.1% and 9.9% were at medium and high physical activity levels, respectively, for females. Medium and high physical activity levels were lower in females than in males. The overweight rate of adolescents in this study survey was 11.3% and the obesity rate reached 5.7%. Results show that the proportion of overweight adolescents in the region was more than twice that of obesity, indicating that adolescents in the region have a certain epidemic trend of obesity, and further attention should be paid to the problem of adolescent obesity.

Table 1: PA level and BMI level

PA level	*Male（%）*	*Female(%)*	***Total（%）***
Low level of PA	*105（25.5）*	*227（48.0）*	*332（37.6）*
Moderate level of PA	*213（51.8）*	*199（42.1）*	*213（46.6）*
High level of PA	*93（22.6）*	*47（9.9）*	*140（15.8）*
BMI category	*Male（%）*	*Female(%)*	***Total（%）***
Thin	20（4.9）	16（3.4）	36（4.1）
Normal	291（70.8）	386（81.6）	677（76.6）
Overweight	76（18.5）	45（9.5）	121（13.7）
Obesity	24（5.8）	26（5.5）	50（5.7）

A survey of adolescents' food intake frequency was conducted with the aim of understanding the frequency of adolescents' intake of specific types of foods, rather than trying to quantify their food intake. An attempt was made to use vegetables and fruits as healthy food groups and fried foods, puffed foods, candy, ice cream ice-cream, sugary drinks, and carbonated drinks as unhealthy food groups in this study. The frequency and ratio of regular intake of healthy foods to unhealthy foods among adolescents are shown in Table 2.

Table 2: Frequency of intake of various food groups in adolescents

Food category	Frequency	Total（%）	Male（%）	Female（%）
Fresh vegetables	Never	8（0.9）	4（1.0）	4（0.8）
	Occasionally	395（44.7）	139（33.8）	139（54.1）
	Frequently	481（54.4）	268（65.2）	268（45.0）
Fresh fruits	Never	20（2.3）	9（2.2）	9（2.3）
	Occasionally	340（38.5）	192（46.7）	192（31.3）
	Frequently	524（59.3）	210（51.1）	210（66.4）
Fried foods	Never	30（3.4）	15（3.6）	15（3.2）
	Occasionally	704（79.6）	335（81.5）	335（78.0）
	Frequently	150（17.0）	61（14.8）	61（18.8）
Puffed foods	Never	49（5.5）	19（4.6）	19（6.3）
	Occasionally	653（73.9）	317（77.1）	317（71.0）
	Frequently	182（20.6）	75（18.2）	75（22.6）
Sugar foods	Never	39（4.4）	18（4.4）	18（4.4）
	Occasionally	697（78.8）	333（81.0）	333（77.0）
	Frequently	148（16.7）	60（14.6）	60（18.6）
Ice cream	Never	46（5.2）	21（5.1）	21（5.3）
	Occasionally	637（72.1）	309（75.2）	309（69.3）
	Frequently	201（22.7）	81（19.7）	81（25.4）
Sugary beverages	Never	43（4.9）	24（5.8）	24（4.0）
	Occasionally	629（71.2）	285（69.3）	285（72.7）
	Frequently	212（24.9）	102（24.8）	102（23.3）
Carbonated beverages	Never	45（5.1）	27（6.6）	27（3.8）
	Occasionally	680（76.9）	309（75.2）	309（78.4）
	Frequently	159（18.0）	75（18.2）	75（17.8）

4.2 Correlation between physical activity environment and physical activity level

Table 3 shows that all indicators of the physical environment in the settlement were correlated with the physical activity level of adolescents, while being significant ($p < 0.05$ or $p < 0.01$). After differentiating between genders, it was found that C1 (physical activity facilities around the settlement are extremely suitable for use), C2 (many and types of physical activity places around the settlement), C3 (physical activity places around the settlement are very close), C4 (it is convenient to go to physical activity places around the settlement), C8 (there are few stray dogs around the settlement), C9 (physical activity around the settlement is newer and well-maintained), C14 (physical activity around the settlement (there are many promotional messages promoting physical activity in the surrounding area) were positively

correlated with the physical activity level of male adolescents ($p<0.05$ or $p<0.01$). With the exception of C10 (good environmental hygiene in the vicinity of the settlement) and C14, which did not have significant correlations with the physical activity level of female adolescents ($p>0.05$), all physical environment indicators of the settlement were correlated with the physical activity level of adolescents and were significant ($p<0.05$ or $p<0.01$).

Table 3: Correlation between PA environment and PA level of adolescents

PA environment		Male-PAQ	Female-PAQ	Total-PAQ
C1	r	0.113*	0.201**	0.152**
C2	r	0.111*	0.155**	0.139**
C3	r	0.119*	0.162**	0.144**
C4	r	0.106*	0.143**	0.131**
C5	r	0.075	0.186**	0.129**
C6	r	0.059	0.144**	0.097**
C7	r	0.065	0.133**	0.100**
C8	r	0.152**	0.181**	0.160**
C9	r	0.131**	0.237**	0.164**
C10	r	0.049	0.084	0.077*
C11	r	0.050	0.186**	0.121**
C12	r	0.066	0.170**	0.122**
C13	r	0.076	0.124**	0.093**
C14	r	0.134**	0.035	0.093**
C15	r	0.096	0.103**	0.075*

Note: ** indicates significant correlation at 0.01 level (two-sided); * indicates significant correlation at 0.05 level (two-sided)

4.3 Correlation between food environment and frequency of food intake

Table 4 shows that in the correlation analysis between the food environment and the frequency of food intake in the sample's overall residence, a positive correlation exists between C24 (proximity of the residence to fruit and vegetable vending machines) and C25 (retail food in the residence basically did not exceed the shelf life) and the frequency of vegetable intake ($p < 0.05$); C17 (few unhealthy snack vending machines around the home), C24, C25, and the frequency of fruit intake ($p < 0.05$); C21 (few high-calorie food vending machines around the home), C24, C25 and the frequency of fried food intake ($p < 0.05$). ($p < 0.05$); C21 (few high-calorie food vending machines around home), C24, C25 and fried food had a positive correlation ($p < 0.05$ or $p < 0.01$); C25 had a negative correlation ($p < 0.05$) with the frequency of candy intake; C24 had a negative correlation ($p < 0.05$) with the frequency of ice cream intake; C23 (more fruit and vegetable vending outlets around home) had a positive correlation ($p < 0.05$). (further fruit and vegetable vending outlets around the home), C25 and C27 (better promotion of healthy eating information around the home) were negatively correlated with the frequency of intake of sugary drinks ($p < 0.05$); C21 and C23 were negatively correlated with the frequency of intake of carbonated drinks ($p < 0.05$).

Table 4: Correlation between food environment and frequency of food intake in adolescents (all)

Food environment		**Fresh vegetables**	**Fresh fruits**	**Fried foods**	**Puffed foods**	**Sugar foods**	**Ice cream**	**Sugary beverages**	**Carbonated beverages**
C16	r	0.031	0.016	-0.029	-0.036	0.030	-0.055	-0.037	-0.027
C17	r	0.059	0.067*	-0.059	-0.019	0.034	-0.055	-0.034	-0.055
C18	r	0.063	0.030	-0.064	-0.023	0.040	-0.003	0.010	0.007
C19	r	0.064	0.015	-0.041	-0.012	0.002	-0.042	0.017	-0.009
C20	r	0.010	0.049	-0.017	-0.018	0.010	-0.012	-0.010	-0.010
C21	r	0.045	0.063	-0.092**	-0.021	0.003	-0.045	-0.055	-0.077*
C22	r	0.065	0.014	0.007	0.025	0.027	-0.046	0.001	0.016
C23	r	0.055	0.061	-0.042	-0.025	-0.054	-0.028	-0.079*	-0.108*
C24	r	0.080*	0.068*	-0.069*	0.014	-0.079*	-0.027	-0.077*	-0.057
C25	r	0.083*	0.077*	-0.096**	-0.032	-0.035	-0.067*	-0.079*	-0.048
C26	r	0.043	0.004	-0.034	0.004	-0.050	-0.045	-0.046	-0.025
C27	r	0.048	-0.017	0.004	0.008	0.011	-0.012	-0.069*	-0.006

Note: ** indicates significant correlation at 0.01 level (two-sided); * indicates significant correlation at 0.05 level (two-sided)

After differentiating by gender, Table 5 shows that in the correlation analysis between the food environment of the residence and the frequency of food intake among male adolescents, C17 (fewer unhealthy snack vending outlets around the home), C21 (fewer high-calorie food vending machines around the home), and C25 (retail food in the residence basically did not exceed the shelf life) were positively correlated with the frequency of fresh vegetable intake ($p < 0.05$ or $p < 0.01$); C21 and C26 (fewer pesticide residues used in fruits and vegetables around the home) were negatively correlated with the frequency of fried food intake ($p < 0.05$). A negative correlation exists between C21 and C26 (less pesticide residues used in fruits and vegetables around home) and the frequency of fried food intake ($p < 0.05$); C24 (proximity of residence to fruit and vegetable vending outlets) and the frequency of candy intake ($p < 0.05$); C23 (more fruit and vegetable vending outlets around home), C25, C26, and the frequency of sugary drinks intake ($p < 0.01$ or $p < 0.05$); C21 and C23 were negatively correlated with the frequency of carbonated beverage intake ($p < 0.01$ or $p < 0.05$). Table 6 shows that the correlation analysis between the food environment of female adolescents' residence and the frequency of food intake shows that no statistically significant correlation exists between the frequency of food intake and the food environment of the residence, except for the correlation between the frequency of food intake of puffed food, candy, sugary drinks, and carbonated drinks ($p > 0.05$), in which a positive correlation exists between C24 and the frequency of vegetable intake ($p < 0.05$); C24 and C25 had a positive correlation with the frequency of fruit intake ($p < 0.05$); C25 had a negative correlation with the frequency of fried food intake ($p < 0.05$); C25 and C26 had a negative correlation with the frequency of ice cream type intake ($p < 0.01$).

Table 5: Correlation between food environment and frequency of food intake in males

Food environment		Fresh vegetables	Fresh fruits	Fried foods	Puffed foods	Sugar foods	Ice cream	Sugary beverages	Carbonated beverages
C16	r	0.084	-0.016	-0.067	-0.012	0.012	-0.046	-0.025	-0.051
C17	r	0.104*	0.093	-0.056	-0.022	-0.032	-0.027	-0.013	-0.109*
C18	r	0.088	0.079	-0.090	-0.016	0.016	0.013	0.007	-0.040
C19	r	0.079	0.036	-0.038	0.012	0.015	-0.030	0.067	-0.064
C20	r	0.010	0.062	-0.037	-0.022	0.035	0.003	0.059	-0.013
C21	r	0.108*	0.031	-0.125*	0.011	-0.017	-0.062	-0.054	-0.122*
C22	r	0.009	0.046	0.003	0.012	0.011	-0.018	0.076	-0.014
C23	r	0.079	0.013	-0.062	-0.040	-0.081	-0.046	-0.132**	-0.146**
C24	r	0.083	0.006	-0.056	0.028	-0.103*	-0.014	-0.082	-0.096
C25	r	0.137**	0.059	-0.087	0.006	-0.028	-0.028	-0.116*	-0.078
C26	r	0.036	0.014	-0.127*	-0.014	-0.067	0.027	-0.106*	-0.092
C27	r	0.063	0.028	0.013	-0.024	0.027	0.036	-0.094	-0.046

Note: ** indicates significant correlation at 0.01 level (two-sided); * indicates significant correlation at 0.05 level (two-sided)

Table 6: Correlation between food environment and frequency of food intake in females

Food environment		Fresh vegetables	Fresh fruits	Fried foods	Puffed foods	Sugar foods	Ice cream	Sugary beverages	Carbonated beverages
C16	r	-0.006	0.043	-0.002	-0.055	0.041	-0.064	-0.048	-0.005
C17	r	0.026	0.046	-0.063	-0.017	0.087	-0.077	-0.053	-0.004
C18	r	0.009	0.016	-0.040	-0.026	0.065	-0.005	0.013	0.051
C19	r	0.010	0.029	-0.038	-0.025	0.003	-0.043	-0.031	0.045
C20	r	-0.010	0.053	0.004	-0.013	-0.004	-0.018	-0.072	-0.004
C21	r	0.007	0.086	-0.069	-0.047	0.016	-0.033	-0.055	-0.036
C22	r	0.089	0.003	0.012	0.036	0.045	-0.062	-0.074	0.045
C23	r	0.056	0.089	-0.029	-0.015	-0.038	-0.020	-0.029	-0.074
C24	r	0.093*	0.115*	-0.081	0.002	-0.063	-0.041	-0.069	-0.021
C25	r	0.037	0.098*	-0.104*	-0.062	-0.041	-0.099*	-0.046	-0.019
C26	r	0.039	0.005	0.042	0.021	-0.033	-0.098*	0.009	0.038
C27	r	0.012	-0.041	0.001	0.038	0.001	-0.045	-0.047	0.035

Note: ** indicates significant correlation at 0.01 level (two-sided); * indicates significant correlation at 0.05 level (two-sided)

4.4 Logistic regression of physical activity level and frequency of food intake with whether adolescents are obese

Based on the analysis of the differences in BMI levels between groups with various physical activity levels and food intake frequencies, this study focused on examining the effects of physical activity levels and food intake frequencies on the obesity rate of adolescents. The dependent variable was a dichotomous variable: whether the adolescent was obese or not, which was based on the height and weight data of the adolescent, as well as the individual BMI score was calculated to determine whether the adolescent was obese or not, with a value of 1 if the adolescent was obese and 0 if not. The independent variables included: physical activity level, fresh vegetables, fresh fruits, fried food, puffed food, candy, ice cream, sugary drinks, and carbonated drinks food intake frequency. Exercise preference and fruit and vegetable preference were included in this study to ensure that the results are accurate. Considering that obesity in adolescents may be genetically derived, this section also includes parental BMI, age, and household income in the study.

Binary Logistic Regression was selected to explore the correlation between physical activity level, food intake frequency and whether adolescents were obese according to the dependent variable as a dichotomous variable. The independent variable was the type of physical activity in model 1; in model 2, the independent variable was the frequency of food intake; in model 3, the independent variables were physical activity level and food intake frequency, and each of the above three models incorporated possible confounding factors: age, exercise preference, fruit and vegetable preference, total monthly household income, and parents' BMI. Table 7 shows that in model 1, when the independent variable was physical activity level, the correlation coefficient between physical activity level of adolescents and whether they are obese correlation is small and the significance level is insignificant. In model 2, when the independent variable was the frequency of intake of various types of food, the frequency of intake of fried food (OR=1.779, p<0.05), puffed food (OR=1.729, p<0.05) and carbonated drinks (OR=2.031, p<0.05) were risk factors for obesity in adolescents. When the independent variables were physical activity level and frequency of food intake in Model 3, the frequency of intake of fried food (OR=1.771, p<0.05) puffed food (OR=1.762, p<0.05) and carbonated beverages (OR=2.082, p<0.05) remained as risk factors for adolescent obesity, while the correlation coefficient between adolescent physical activity level and obesity correlation remained smaller, and the significance level was not statistically significant.

Table 7: Logistic regression analysis of whether adolescents (all) are obese and physical activity and frequency of food intake

	Model 1		*Model 2*		*Model 3*	
	OR	*95%CI*	*OR*	*95%CI*	*OR*	*95%CI*
PA level	*0.836（0.636，1.099）*				*0.793（0.595，1.055）*	
Fresh vegetables			*0.895（0.630，1.271）*		*0.919（0.645，1.308）*	
Fresh fruits			*0.921（0.655，1.296）*		*0.931（0.661，1.310）*	
Fried foods			*1.779（1.184，2.674）**		*1.771（1.176，2.666）**	
Puffed foods			*1.729（1.193，2.505）**		*1.762（1.213，2.56）**	
Sugar foods			*1.095（0.739，1.623）*		*1.081（0.728，1.604）*	
Ice cream			*1.151（0.798，1.66）*		*1.155（0.800，1.667）*	
Sugary beverages			*1.389（0.945，2.041）*		*1.383（0.94，2.034）*	
Carbonated beverages			*2.031（1.381，2.987）**		*2.082（1.412，3.069）**	

Note: Each model controls for age, preference for exercise, preference for fruits and vegetables, total monthly household income, and parental BMI *p < 0.05, both significantly correlated, **p < 0.01, both very significantly correlated.

After differentiating by gender, Table 8 shows that the correlation coefficients for the correlation between physical activity level and the presence of obesity among male adolescents in Model 1 were small and the level of significance was insignificant. The frequency of intake of fried food (OR=2.267, p<0.05) and carbonated beverages (OR=1.813, p<0.05) were risk factors for obesity in male adolescents in Model 2. The frequency of fried food (OR=2.402, p<0.05) and carbonated beverage (OR=1.884, p<0.05) intake were risk factors for obesity in Model 3, while the correlation coefficients for the correlation between adolescent physical activity level and whether they were obese were small and the significance level was insignificant. For female adolescents, the correlation coefficient between physical activity level and obesity correlation in model I was smaller and the significance level was not statistically significant. The frequency of intake of puffed food (OR=2.499, p<0.05) and carbonated beverages (OR=2.462, p<0.05) in Model 2 was a risk factor for obesity in female adolescents. When physical activity level and food intake frequency were included in Model 3, the frequency of puffed food (OR=2.634, p<0.05) and carbonated beverage (OR=2.557, p<0.05) intake remained as risk factors for obesity in female adolescents. The correlation coefficient between

physical activity level and obesity correlation in adolescents was small and the level of significance was insignificant.

Table 8: Logistic regression analysis of whether male/female adolescents are obese and physical activity category and frequency of food intake

Male	*Model 1*		*Model 2*		*Model 3*	
	OR	95%*CI*	OR	95%*CI*	OR	95%*CI*
PA level	0.769（0.526，1.125）				0.690（0.461，1.032）	
Fried foods			2.267（1.262，4.071）*		2.402（1.324，4.357）*	
Carbonated beverages			1.813（1.104，2.979）*		1.884（1.142，3.107）*	
Female	*Model 1*		*Model 2*		*Model 3*	
	OR	95%*CI*	*OR*	95%*CI*	*OR*	95%*CI*
PA level	1.095（0.739，1.623）				0.670（0.421，1.067）	
Puffed foods			2.499（1.428，4.372）*		2.634（1.492，4.649）*	
Carbonated beverages			2.462（1.351，4.488）*		2.557（1.395，4.688）*	

Note: Each model controls for age, preference for exercise, preference for fruits and vegetables, total monthly household income, and parental BMI *p < 0.05, both significantly correlated, **p < 0.01, both significantly correlated.

4.5 Logistic regression of physical activity environment, food environment and whether adolescents are obese

Binary Logistic Regression was chosen to analyze physical activity environment and food environment with whether adolescents were obese by logistic regression, and three models were set up simultaneously, the independent variables in model one were physical activity environment indicators (C1-C15); the independent variables in model two were food environment indicators (C16-C27); model three included both physical activity and food environment (C1-C27), and the confounding factors included in each model included age, exercise preference, fruit and vegetable preference, total monthly household income, and parents' BMI level. We analyzed the correlation between physical activity environment and food environment and adolescents' obesity and compared whether the correlation between the combined "physical activity environment" and "food environment" and adolescents' obesity was stronger than that of the single "physical activity environment" or "food environment." Table 9 shows that the correlation between Models 1 and 2 is stronger than that between Models 3 and 4. Table 9 shows that C7 (OR=0.629, p<0.05), C8 (OR=0.764, p<0.05), C12 (OR=0.648, p<0.05), and C15 (OR=0.638, p<0.05) in Model 1 are protective factors for adolescent obesity. In Model 2, C16 (OR=0.744, p<0.05), C17 (OR=0.695, p<0.05), and C20 (OR=0.767, p<0.05) were risk factors for adolescent obesity. When both physical activity environment and food environment were included in Model 3, the combined "physical activity environment and food environment" of C7 (OR=0.657, p<0.05), C8 (OR=0.766, p<0.05), C12 (OR=0.661, p<0.05), C15 (OR= 0.686, p < 0.01) were protective factors for adolescent obesity.

Table 9: Logistic regression of whether adolescents (all) are obese and PA environment and food environment

Total	*Model 1*		*Model 2*		*Model 3*	
	OR	95%*CI*	*OR*	95%*CI*	*OR*	95%*CI*
C1	1.080（0.762，1.532）				1.078（0.751，1.548）	
C2	0.977（0.685，1.393）				0.979（0.675，1.418）	
C3	0.754（0.536，1.060）				0.763（0.533，1.092）	
C4	1.031（0.719，1.478）				1.042（0.716，1.517）	
C5	0.901（0.726，1.118）				0.951（0.758，1.194）	
C6	0.907（0.798，1.032）				0.924（0.809，1.056）	
C7	0.629（0.459，0.861）*				0.657（0.473，0.913）*	
C8	0.764（0.594，0.983）*				0.766（0.589，0.998）*	
C9	1.017（0.767，1.350）				0.984（0.738，1.312）	
C10	1.208（0.930，1.570）				1.195（0.912，1.567）	
C11	0.995（0.744，1.331）				0.914（0.674，1.240）	
C12	0.648（0.492，0.855）*				0.661（0.496，0.881）*	
C13	1.040（0.773，1.400）				1.040（0.761，1.421）	
C14	1.219（0.951，1.563）				1.199（0.916，1.569）	
C15	0.638（0.519，0.785）*				0.686（0.549，0.858）**	

C16		0.744（0.560，0.989）*	0.798（0.584，1.090）
C17		0.695（0.515，0.939）*	0.744（0.530，1.045）
C18		0.869（0.664，1.137）	0.939（0.700，1.260）
C19		1.27（0.956，1.686）	1.256（0.915，1.724）
C20		0.767（0.609，0.967）*	0.772（0.594，1.004）
C21		0.868（0.706，1.066）	0.916（0.725，1.157）
C22		1.185（0.929，1.511）	1.135（0.861，1.495）
C23		0.82（0.619，1.086）	0.991（0.721，1.362）
C24		0.972（0.740，1.278）	1.104（0.813，1.500）
C25		0.958（0.774，1.185）	0.933（0.730，1.192）
C26		0.854（0.660，1.105）	0.998（0.743，1.341）
C27		1.005（0.812，1.244）	1.058（0.822，1.362）

Note: Each model controls for age, preference for exercise, preference for fruits and vegetables, total monthly household income, and parental BMI *p < 0.05, both significantly correlated, **p < 0.01, both very significantly correlated.

After differentiating between genders, C7 (OR=0.652, p<0.05) and C15 (OR=0.664, p<0.05) in Model I were protective factors for obesity in male adolescents, as shown in Table 10. Model II C18 (OR=0.596, p<0.05) was a protective factor for obesity in male adolescents. When physical activity environment indicators were included in Model III, only C18 (OR=0.596, p<0.05) in physical activity environment indicators was a protective factor for obesity in male adolescents in the combined "physical activity environment and food environment". In the group of girls, C8 (OR=0.0515, p<0.05), C12 (OR=0.539, p<0.05) and C15 (OR=0.527, p<0.05) in Model 1 were protective factors for obesity in female adolescents; C16 (OR=0.591, p<0.05) in model 2. When both physical activity environment and food environment indicators were included in Model III, the combined "physical activity environment and food environment" of C8 (OR=0.539, p<0.05), C12 (OR=0.479, p<0.05), C15 (OR=0.571, p<0.05), C16 (OR=0.540, p<0.05), and C16 (OR=0.540, p<0.05) were the protective factors against obesity in female adolescents. OR=0.540, p<0.05) were protective factors for obesity in female adolescents.

Table 10: Logistic regression of whether male/female adolescents are obese with PA environment and food environment

Male Environment	*Model 1*		*Model 2*		*Model 3*	
	OR	95%*CI*	*OR*	95%*CI*	*OR*	95%*CI*
C7	0.652（0.427，0.994）*				0.717（0.455，1.129）	
C15	0.664（0.489，0.902）*				0.745（0.529，1.049）	
C18			0.636（0.413，0.979）*		0.596（0.367，0.968）*	
Female Environment	*Model 1*		*Model 2*		*Model 3*	
	OR	95%*CI*	*OR*	95%*CI*	*OR*	95%*CI*
C8	0.515（0.336，0.789）*				0.539（0.340，0.853）*	
C12	0.539（0.348，0.834）*				0.497（0.304，0.813）*	
C15	0.527（0.381，0.728）*				0.571（0.398，0.820）*	
C16			0.591（0.379，0.922）*		0.540（0.319，0.912）*	

Note: Each model controls for age, preference for exercise, preference for fruits and vegetables, total monthly household income, and parental BMI *p < 0.05, both significantly correlated, **p < 0.01, both extremely significantly correlated.

5. DISCUSSION

5.1 Analysis of physical activity level, frequency of food intake and BMI level in adolescents

This study's results show that the overall physical activity level of the sample was low, with females having a lower percentage of cases of moderate physical activity and high physical activity than males. This may be due to the uneven physiological development of males and females; females tend to increase body fat during adolescence, while males increase muscle mass, which facilitates their physical activity (Waylen and Wolke, 2004); females have a lower physical self-concept, and males are usually more confident, braver, and more motivated to achieve than females, wherein the females' personalities are less conducive to physical activity compared to males (Kirch *et al*., 2021); adolescents of various genders. There are differences in the process of socialization, and families and schools tend to assign different social norms and roles to males and females in the process of individual growth. In family education, parents usually encourage boys to participate in confrontational sports such as soccer and basketball to cultivate their bravery, independence, and sense of competition through sports,

while supporting girls to participate in dance sports to cultivate their gentle and soft temperament, wherein the boys' medium- and high-intensity physical activity levels are somewhat higher than those of girls. In school education, the design of physical education materials and educational contents are mainly based on athletics, ball games, and martial arts, and such sports have masculine temperament such as strength, speed, and competition, and the corresponding venue facilities are more complete; while sports with feminine temperament such as aerobics, sports dance, and yoga, the campus venue construction is incomplete and cannot fulfill the girls' sports interests and sports needs (Gabriel *et al.*, 2020). This study shows that adolescents frequently consume a high proportion of non-healthy foods. Unhealthy eating behaviors are prevalent among adolescents, while the resulting health problems are becoming increasingly significant. Adolescence is a critical period for the formation of eating behaviors, and the eating behaviors established during this period have an important impact on the health of adolescents themselves and in adulthood (Emily *et al*., 2019).

5.2 Relationship between physical activity level, frequency of food intake and BMI level in adolescents

This study shows that no significant difference exists in BMI between different physical activity levels in the sample overall and among male adolescents, but there was a significant difference in BMI between different physical activity levels among female adolescents. Some studies are consistent with the results of this paper, Mota *et al.*, reported that physical activity levels were higher in normal weight girls than in obese girls, but there were no significant differences in physical activity in boys (Mota *et al*., 2005). The results of a recent study also revealed that moderate to high intensity physical activity levels reduced the risk of obesity in female adolescents, but not statistically significant in male adolescents, suggesting a gender difference in the relationship between physical activity and adolescent obesity (Mo *et al*., 2022). The reason for this analysis may be due to the fact that males prefer to exercise and participate in further physical activity compared to females, but may consume more food and soft drinks after exercise, compensating for the energy expended during exercise. However, the relationship between physical activity and weight status remains unclear from the results of available studies, and the results of existing studies lack a consistent correlation. For example, lack of physical activity in adolescents is associated with higher BMI levels (Marques *et al*., 2015 ; Crowe *et al*., 2020), but some studies have also shown no association between physical activity levels and BMI in adolescents (Aires *et al*., 2010). Lee *et al*., found that while participation in organized physical activity in adolescents can increase PA or MVPA, the effect on obesity remains uncertain (Lee *et al.*, 2018). With regard to the relationship between food intake behavior and weight status, the consistency of the available studies is good. The intake of foods high in salt, oil, and fat, as well as sugary beverages, can increase energy intake, which increases the risk of obesity and obesity (Neuhouser, 2019; Gui *et al*., 2017).. Therefore, current research on physical activity interventions for adolescent obesity needs to focus on the effects of food intake behaviors. Enhancing the adolescents' understanding of the dangers of poor eating habits and raising awareness of the importance of healthy eating habits is also important.

5.3 Relationship between physical activity environment and physical activity level, food environment and frequency of food intake

This study showed that all indicators of physical activity environment were positively correlated with physical activity levels of adolescents. Some studies have shown that the lack of community sports facilities is positively associated with physical inactivity (Li *et al*., 2006), and the distance to various types of facilities, parks, and schools also plays an important role in physical activity. For example, a negative correlation exists between commuting time to the nearest sports facility and the likelihood of meeting physical activity recommendations (Guo *et al*., 2015). Some studies have shown that road hazards (e.g., stray dogs) are significantly and negatively associated with adolescents' choice to travel on foot or by bicycle (Davison and Lawson, 2006). Improving the safety of facilities in and around settlements and activity areas facilitates adolescents' participation in physical activity. Adolescents have better perceptions of well-maintained and clean recreational facilities, but are repelled by community sanitation issues such as illegal dumping of trash, dirt in activity areas, and poor air, which can discourage physical activity in the community (Mitas *et al*., 2018; Van Hecke *et al*., 2018). The level of physical activity of adolescents is limited by the presence or absence of fees for sports venues around the settlement, and the cost of adolescent sports is relatively higher when only fee-based sports venues are available around the settlement. Without a fixed income, the youth group may have less sporting options and less time for physical activity, which affects the youth's participation in sports activities to some extent. Sports-related information everywhere in the community can constitute a positive sports climate, for example, in foreign studies related to sports equipment and sign lines on asphalt fields, which can motivate adolescents to participate in physical activity (Willenberg *et al*., 2010).

In the correlation analysis between food environment and food behavior, a positive correlation exists between healthy food intake behavior and food environment among adolescents. The influence of food environment on eating behaviors has been confirmed by numerous national and international studies, some of which revealed that the availability of fast food outlets, restaurants and convenience stores in the community

had a negative effect on adolescents' dietary intake (Ho *et al*., 2010); living in a community with fewer fast food outlets and convenience stores was associated with a lower likelihood of eating out and snacking (Van Hulst *et al*., 2012); and the intake of sugary beverages was associated with the proximity of restaurants near the adolescent's residence (Laska *et al.*, 2010). Strengthening posters and advertisements promoting healthy eating and dietary nutrition around the settlements may improve poor eating habits. This study also indicates that a relationship exists between food safety and eating behavior; adolescents generally believe that organic food without pesticides is beneficial to health and are more inclined to buy it (Akhtar and Nisar, 2016).

5.4 Relationship between physical activity environment, food environment and whether adolescents are obese

Among the physical activity environment indicators, better physical activity venues in and around the residence were protective factors for adolescent obesity. The results are consistent with previous studies that the safety of the residential environment may influence the number of recreational and playful outings of adolescents, with more secure neighborhoods having significantly further physical activity and parents being more comfortable with their adolescents going out to play (Mitas *et al*., 2018b ; Bungum *et al*., 2009), and conversely less secure neighborhoods with insufficient physical activity may significantly increase the risk of obesity (Davison and Lawson, 2006b). Better physical activity venues and amenities in and around the settlement are more likely to attract adolescents to go for physical activities, thus reducing the risk of obesity among adolescents. Many studies based on numerical relationships have shown that shaded trees in public open spaces are positively associated with after-school physical activities in adolescent females, who conduct more moderate-to-vigorous physical activities after school (Timperio *et al*., 2017). Women are reluctant to participate in sports for fear of getting a tan or getting wet due to weather, and improving the comfort of physical activity venues or sports facilities may counteract this resistance, promote physical energy expenditure to some extent, and reduce the risk of obesity.

In terms of food environment factors, individuals in relatively healthy food environments have a reduced risk of adolescent obesity. The residential surroundings provide adolescents with possible exposure to high-sugar, high-fat, and high-calorie foods, which in turn can lead to an increased risk of adolescent obesity (Heinrich *et al*., 2008). This paper also indicates that these foods are expensive and the less frequently male adolescents purchase them, the lower the detection rate of obesity, possibly because male adolescents have less pocket money. Recognizing the importance of the environment and the complexity of the causes of obesity decisions, attempts to isolate the effects of individual environmental characteristics on health may be incomplete. Thus, this paper attempts to combine attributes related to the food environment and physical activity environment into a composite measure to characterize the "obesogenicity" of the residential environment. Similar to other studies, Kan *et al*., showed that bus stop density was negatively and significantly associated with obesity in a single "physical activity environment" model, but in a combined "physical activity environment and food environment" model, the significance level in the combined "physical activity environment and food environment" model was insignificant (Oishi *et al*., 2021). The reason for this is that the presence of food environment may confound the relationship between physical activity environment and obesity, and that food environment and physical activity environment may interact with each other. Therefore, in physical health interventions, focusing on the influence of the combined "physical activity environment" and "food environment" in female adolescents is necessary and feasible.

5.5 Limitations

1. The physical activity level, food intake frequency, and residential environment data in this study were obtained from self-reports and recollections of the respondents, and the methodology of food intake frequency survey is difficult, so there may be some deviation from the real situation. Meanwhile, the sample size was insufficient and unbalanced, which was influenced by the "new pneumonia" epidemic and the special characteristics of the senior group, such as high academic pressure and less free time, which reduced the validity and representativeness of the analysis results of adolescents to some extent.
2. There are many factors affecting the physical activity level of adolescents, and their behavior is the result of the combined effect of various environments (including school environment, family environment, and community environment). The analysis exploring the effects of residential physical activity environment and food environment on adolescents' BMI was inevitably interfered by the aforementioned environments. This study is a cross-sectional survey, which can only explore the correlation among residential physical activity environment, food environment, and BMI, and explaining the influence pathway and further grasp the obesity pattern is difficult.

5.6 Advantages

1. This study follows the international trend of integrating physical activity environment and food environment into "obesity environment" and correlates with BMI level of adolescents, and systematically compiles relevant measurement tools, influencing factors and confounding factors,

which can help provide a preliminary theoretical foundation for future development in this field. The research results on the correlation between the physical activity environment and food environment in residential areas and adolescent obesity can simultaneously provide references for the formulation of relevant policies at home and abroad, and also provide new ideas for the promotion of adolescent physical health at home and abroad.

2. The study of the correlations between physical activity environment and food environment in urban adolescent settlements and adolescents' food intake behavior, physical activity, and weight status can help enrich the cross-sectional "correlations" results in this field in Chinese cities. The selection of relevant measurement instruments and the inclusion of confounding factors can provide methodological references for future research in this area in China and abroad.

6. CONCLUSION

1. The study revealed that the overall physical activity level of adolescents was low and the frequency of unhealthy food intake such as fried food, puffed food and carbonated drinks was high. The differences in BMI between groups with various physical activity levels were small and statistically insignificant, but the differences in BMI levels between groups with different frequencies of unhealthy food intake were large and significant. Therefore, the impact of food intake behavior needs to be paid attention to in the current study of physical activity interventions for adolescent obesity.
2. The distribution of better physical activity environment and food environment in and around the residence resulted in adolescents presenting lower BMI levels. The results also exhibited that physical activity environment and food environment were significantly correlated with physical activity level and frequency of unhealthy food intake among adolescents. Therefore, optimizing the physical activity environment and food environment in and around the residence has positive implications for adolescents' physical activity levels and healthy food intake behavior.
3. Among female adolescents, the indicators of single physical activity environment or single food environment that were significantly correlated with BMI level were consistent with the indicators that were significantly correlated with the combined "obesity environment". However, the types of indicators significantly associated with single and combined environments differed significantly among male adolescents. Therefore, focusing on the influence of the combined "physical activity environment and food environment" is necessary.

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Appendix I:

Demographic Sociology

Part I: Student Questionnaire

Please draw " √ " in the option that matches your actual situation or fill in the relevant information online.

1. Grade Level：

2. Gender：

3. Ethnicity：

4. Age：_____ Height：_____cm Weight：_____kg

5. Have you ever suffered from a congenital disease or physical defect detrimental to exercise?
□ Yes □ No

6. What type of family are you?
□Two-Parent Families □Single-Parent Families
□Reorganization Families □Other Types

7. Are you the only child in your family?
□ Yes □ No

8. What family members do you live with? (You may choose more than one)
□Grandparents □Father □Mother
□Stepfather □Stepmother □Siblings □Other Relatives

9. What is your primary caregiver?
□Grandparents □Father □Mother
☐Nannies：_____(Fill in the age of the nannies) □Other Relatives

10. Are you near-sighted?
□ Yes □ No

11. Do you enjoy walking, Tai Chi, or sports (table tennis, badminton, tennis, soccer, basketball, volleyball) or fitness?
□Yes, very □Yes, a little □No □Not at all

12. How much do you like fruits or vegetables?
□Yes, very □Yes, a little □No □Not at all

13. What types of food do you like?
□Vegetarianism □Carnivorism
□Eat more meat and fewer vegetables □Eat more vegetables and less meat

14. Do you think exercise affects your mental state?
□Yes, very □Depends □Not at all

Part I: Parent Questionnaire

1. Your father's occupation:_____Height：_____cm Weight：_____kg
2. Your mother's occupation:_____Height：_____cm Weight：_____kg

3. What is your monthly household income?
□Less than 4000 RMB □4001~6000 RMB □6001~8000 RMB
□8001~10000 RMB □10001~15000 RMB □15001~20000 RMB
□More than 20001RMB

4. Your permanent home address:

5. What is your father's education level?
□Primary School and below □Junior High School □High school or junior college
□College or university □Master and above

6. What is your mother's education level?
□Primary School and below □Junior High School □High school or junior college
□College or university □Master and above

7. How do you feel about the opinion that "physical activity is good for health" and "eating a diet with lots of fruits and vegetables is good for health"? (Completed by the child's primary caregiver)
□Totally agree □Agree □Disagree □Highly Disagree

8. How do you feel about the importance of physical activity for children and the importance of a healthy diet for children? (Completed by the child's primary caregiver)
□Highly agree □Totally Agree □Agree □Disagree □Highly Disagree

9. Was your mother a chronic alcoholic?
☐ Yes □ No
10 Was your father a chronic alcoholic?
□ Yes □ No

11. Does your mother smoke?
□ Yes □ No

12. Does your father smoke?
□ Yes □ No

13. Has your mother ever had a mental illness?
□ Yes □ No

14. Has your father ever had a mental illness?
□ Yes □ No

Appendix II: Physical Activity Questionnaire for Children and Adolescents (PAQ-CN)

	0 times	1-2 times	3-4 times	5-6 times	7 times or more
Jumping rope					
Shuttlecock					
Roller skating					
Catch-up games					
Take a walk or hike					
Cycling					
Jogging					
Fitness Exercise					
Gaming					
Baseball					
Dancing					
Table Tennis					

Badminton					
Skateboarding					
Soccer					
Tennis Ball					
Volleyball					
Martial Arts					
Basketball					
Ice skating					
Hockey					

1. During the past 7 days, what can be summarized as your activity performance in physical education (e.g., running, playing, jumping, throwing, etc.)?
□ Not too fond of gym class.
□ Hardly did any exercise
□ Sometimes
□ Often
□ Always

2. What have you been doing during class breaks in the past 7 days? (Only for elementary school students)
□ Sitting and chatting, reading or doing homework
□ Walking around
□ Doing low-intensity activities outside the classroom
□ Doing moderate-intensity activities outside the classroom
□ Spending most of the time outside

3. In the past 7 days, what did you often do during your lunch breaks?
□ Sitting and chatting, reading or doing homework
□ Walking around
□ Doing low-intensity activities outside the classroom
□ Doing moderate-intensity activities outside the classroom
□ Spending most of the time outside

4. In the past 7 days, how often did you play sports, dance, or play games after school (excluding weekends)?
□ None
□ 1 Time
□ 2-3 Times
□ 4 Times
□ More than 4 times

5. During the past 7 days, how often did you play sports, dance, or play games in the evening?
□ None
□ 1 Time
□ 2-3 Times
□ 4-5 Times
□ More than 6-7 times

6. How often did you play sports, dance, or games during the past weekend?
□ None
□ 1 Time
□ 2-3 Times
□ 4-5 Times
□ More than 6-7 times

7. In the past 7 days, which one best fits your situation?
□ Almost all of my time is taken up by other things, rarely exercise
□ I sometimes do more than 30 minutes of exercise in my free time (1-2 times)
□ I often do 30 minutes of exercise in my free time (3-4 times)
□ I do exercises for 30 minutes very frequently in my free time (5-6 times)
□ I do more than 30 minutes of exercise almost every day in my free time (7 times and more)

8. In the past 7 days, how often did you do the physical activity of 30 minutes or more per day? (Mark " √ " in the corresponding table)

	Never	Seldom	Sometimes	Often	Frequently
Monday					
Tuesday					
Wednesday					
Thursday					
Friday					
Saturday					
Sunday					

9. Did you have an illness or other special event last week that prevented you from performing your daily physical activities?

□ No □ Yes, please state the reasons:

Appendix III:

Physical Activity and Food Environment Assessment Scales

	Subject	Choose only one of these (√)				
		Highly agree	Agree	General	Disagree	Highly disagree
A	**Convenience of activity place facilities**					
	C1. The sports activities around my house are very suitable for use.					
	C2. There are many various types of sports activities around my home.					
	C3. The proximity of sports facilities around my home.					
	C4. It is convenient to go to sports activities from my home.					
	C5. Sports activities around my house are rarely occupied.					
B	**Safety and comfort of the event venue**					
	C6. Traffic is safe on the road between my house and the sports venue.					
	C7. The use of sports activities around my home is safe.					
	C8. There are a few stray dogs around my home.					
	C9. The sports activities around my house are newer and well maintained.					
C	**Facility comfort of the event venue**					
	C10. The environmental health of the sports activities around my house is satisfactory					
	C11. The green landscape of the sports activities around my house is great					
	C12. The supporting facilities for sports activities around my home are perfect					
	C13. The street lights around my house for sports activities are well lit					
D	Information dissemination facilities for sports activities					
	C14. There are many posters, advertisements, boards, and other promotional information around my house to promote physical exercise					
E	**Restrictions on the use of event facilities**					
	C15. Sports and exercise places and facilities around my home are free of charge					
F	**Unhealthy food situation**					
	C16. There are a few high-sugar / high-fat / high-calorie food outlets around my house, such as fried food, cakes, desserts, chips and fries, ice					
	C17. There are few unhealthy snack outlets around my house					
	C18. High-sugar/high-fat/high-calorie foods such as fried foods, cakes and desserts, potato chips, and ice cream are costly around my house, and teenagers buy them less frequently					
	C19. It is not convenient for teenagers to buy fried food, cakes and desserts, potato chips, ice cream, and other high-sugar / high fat / high-calorie food outlets around my house because they are					

	far away.					
	C20. There are no retail vendors of fried foods, cakes and desserts, chips and fries, ice cream, and other high-calorie foods around my house					
	C21. There are a few vending machines around my house for fried foods, cakes and desserts, chips and fries, ice cream, and other high-sugar/ high-fat/high-calorie foods.					
	C22. Fried food, cakes and desserts, chips and fries, ice cream, and other high-sugar/high-fat/high-calorie foods are unavailable for take-out.					
G	**Healthy food environment situation**					
	C23. There are many fresh fruits and vegetables for sale around my house					
	C24. Fresh fruits and vegetables are sold near my home					
	C25. My neighborhood retail food does not see more than the shelf life					
	C26. Few pesticides or residues are used in fruits and vegetables around my house					
H	**The situation of healthy diet information promotion facilities**					
	C27. There are many posters, advertisements, boards, and other information around my house that promote a healthy diet					

Appendix IV:
Food Frequency Questionnaire for Children and Adolescents Aged 6-17 Years in CHINA

Name of food		**Frequency of consumption**			
		Times/day	**Times/week**	**Times /month**	**Hardly eat, fill 0**
Cereals and potatoes					
1	Rice (rice/congee/rice vermicelli/rice noodles, etc.)	☐☐	☐☐	☐☐	☐☐
2	Wheat flour (buns/rolls/noodles/pancakes, etc.)	☐☐	☐☐	☐☐	☐☐
3	Bread	☐☐	☐☐	☐☐	☐☐
4	Fried food	☐☐	☐☐	☐☐	☐☐
5	Corn	☐☐	☐☐	☐☐	☐☐
6	Other grains	☐☐	☐☐	☐☐	☐☐
7	Potatoes	☐☐	☐☐	☐☐	☐☐
8	Groundnut	☐☐	☐☐	☐☐	☐☐
9	Other potatoes (taro/yam, etc.)	☐☐	☐☐	☐☐	☐☐
10	Mixed beans	☐☐	☐☐	☐☐	☐☐
11	Instant Noodles	☐☐	☐☐	☐☐	☐☐
Beans					
12	Soybeans	☐☐	☐☐	☐☐	☐☐
13	Soy milk	☐☐	☐☐	☐☐	☐☐
14	Tofu	☐☐	☐☐	☐☐	☐☐
15	Other Soy Products	☐☐	☐☐	☐☐	☐☐
Vegetables					
16	Fresh vegetables (excluding potatoes)	☐☐	☐☐	☐☐	☐☐
17	Please answer the 5 most frequently eaten vegetables in the past month and their frequency				
17a		☐☐	☐☐	☐☐	☐☐
17a		☐☐	☐☐	☐☐	☐☐
17b		☐☐	☐☐	☐☐	☐☐
17c		☐☐	☐☐	☐☐	☐☐
17d		☐☐	☐☐	☐☐	☐☐
17e		☐☐	☐☐	☐☐	☐☐
18	Dried vegetables	☐☐	☐☐	☐☐	☐☐
19	Kimchi	☐☐	☐☐	☐☐	☐☐
Mycorrhizae					
20	Fresh mushrooms	☐☐	☐☐	☐☐	☐☐
21	Dried mushrooms	☐☐	☐☐	☐☐	☐☐
Fruits					
22	Fresh Fruits	☐☐	☐☐	☐☐	☐☐
23	Please answer the 5 most frequently eaten fresh fruits in the past month and their frequency				
23a		☐☐	☐☐	☐☐	☐☐
23b		☐☐	☐☐	☐☐	☐☐
23c		☐☐	☐☐	☐☐	☐☐
23d		☐☐	☐☐	☐☐	☐☐

23e		□□	□□	□□	□□
24	Dried Fruits	□□	□□	□□	□□
25	Milk	□□	□□	□□	□□
26	Yogurt	□□	□□	□□	□□
27	Powdered Milk	□□	□□	□□	□□
28	Other dairy products	□□	□□	□□	□□
Meat					
29	Lean Pork	□□	□□	□□	□□
30	Fatty pork	□□	□□	□□	□□
31	Streaky Pork	□□	□□	□□	□□
32	Beef	□□	□□	□□	□□
33	Lamb	□□	□□	□□	□□
34	Poultry meat	□□	□□	□□	□□
35	Other Meat	□□	□□	□□	□□
36	Meat products (sausage, ham, luncheon meat, etc.)	□□	□□	□□	□□
37	Animal Livers	□□	□□	□□	□□
38	Blood of animals	□□	□□	□□	□□
39	Other animal organs	□□	□□	□□	□□
Aquatic Products					
40	Fish	□□	□□	□□	□□
41	Shrimps	□□	□□	□□	□□
42	Shellfish (crab/shellfish)	□□	□□	□□	□□
43	Mollusks (squid/cuttlefish, etc.)	□□	□□	□□	□□
Eggs					
44	Fresh Eggs (eggs/quail eggs, etc.)	□□	□□	□□	□□
45	Salted Eggs	□□	□□	□□	□□
46	Preserved Eggs	□□	□□	□□	□□
Snacks					
47	Peanuts	□□	□□	□□	□□
48	Melon seeds	□□	□□	□□	□□
49	Walnuts	□□	□□	□□	□□
50	Chestnuts	□□	□□	□□	□□
51	Other nuts (jacaranda/pistachio, etc.)	□□	□□	□□	□□
52	Pastries (cakes/biscuits/ custard pie peach crumble etc.)	□□	□□	□□	□□
53	Dried beef / fish fillets / shredded squid, etc.	□□	□□	□□	□□
54	Puffed Food	□□	□□	□□	□□
55	Preserves	□□	□□	□□	□□
56	Chocolate	□□	□□	□□	□□
57	Other Candies	□□	□□	□□	□□
58	Ice creams	□□	□□	□□	□□
Beverages					
59	Non-Sugar Added Beverages	□□	□□	□□	□□
60	Sugary beverages	□□	□□	□□	□□
61	Milk drinks (yogurt, etc.)	□□	□□	□□	□□
62	Carbonated beverages	□□	□□	□□	□□
63	Plant protein drinks	□□	□□	□□	□□
64	Pure fruit and vegetable beverage	□□	□□	□□	□□
65	Fruit and vegetable drinks	□□	□□	□□	□□
66	Tea drinks	□□	□□	□□	□□
67	Functional drinks (such as pulse, Wanglaoji, Red Bull, etc.)	□□	□□	□□	□□
68	Other sugary drinks	□□	□□	□□	□□
69	Bottled water	□□	□□	□□	□□
70	Other water	□□	□□	□□	□□
71	Tea	□□	□□	□□	□□
72	Coffee	□□	□□	□□	□□