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Clustering unhealthy lifestyle factors in Chinese children and adolescents with overweight or obesity

Qiong Wang[1,2], Min Yang[3,4], Kening Chen[5], Fangjieyi Zheng[6], Zhixin Zhang[7*] and Wenquan Niu[6*]

Abstract

Background This study used latent class analysis (LCA) to examine the potential patterns of unhealthy lifestyle factors (ULFs) and their association with overweight and obesity in children and adolescents with overweight or obesity in China.

Methods We conducted three cross-sectional surveys, recruiting 7,927 children with obesity or overweight from September 2019 to January 2022. We used LCA to identify patterns of co-occurrence of ULFs based on seven types of behaviors. Multinomial logistic regression model was constructed to examine the association of fetal and neonatal factors with the clusters of ULFs.

Results Of 7,927 participants, 7,627 (96.78%) had at least one ULF, and 6,942 (87.57%) had two or more ULFs concurrently. Using LCA, four distinct clusters were identified based on the elbow point of the Akaike's information criterion (AIC), that is, "unhealthy food intake but long sleeping", "relative health", "healthy food intake but unhealthy eating-sleeping-sitting habits", and "unhealthy food intake and unhealthy sitting-activity habits". Moreover, several factors including sex, age, infancy feeding, parental obesity, and parental age were significantly associated with the clusters of ULFs.

Conclusions We provide evidence on how multiple ULFs in combination may influence health among Chinese children and adolescents with overweight or obesity, and we agree that further external validations are warranted.

Clinical trial number Not applicable.

Keywords Overweight or obesity, Children, Unhealthy lifestyle factors, Latent class analysis

*Correspondence:
Zhixin Zhang
zhangzhixin032@163.com
Wenquan Niu
niuwenquan_shcn@163.com
[1]Graduate School, Beijing University of Chinese Medicine, Beijing, China
[2]Department of Pediatrics, China-Japan Friendship Hospital, Beijing, China
[3]China Academy of Chinese Medical Sciences, Beijing, China
[4]Department of Acupuncture and Moxibustion, Guang'anmen Hospital, Beijing, China
[5]Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China
[6]Center for Evidence-Based Medicine, Capital Institute of Pediatrics, No.2 Yabao Rd., Chaoyang District, 100020 Beijing, China
[7]Institute of Clinical Medicine, China-Japan Friendship Hospital, No.2 Yinghua East Street, Chaoyang District 100029 Beijing, China

Introduction

Childhood and adolescent obesity is rapidly becoming a serious public health problem in China and worldwide. Latest global statistics show that the age-standardized prevalence of obesity in school-aged children and adolescents increased from 1.7% in 1990 to 6.9% in 2022 in girls and from 2.1 to 9.3% in boys [1]. In China, the prevalence of overweight or obesity in children and adolescents aged 6–17 years increased from 3.4% in 2006 to 19.0% in 2022 [2, 3]. Early-life obesity has important consequences for health, as it can persist into adulthood and strongly predict future type 2 diabetes [4], cardiovascular disease [5], and cancer [6]. Effective strategies are hence required to combat the rising prevalence and burden of childhood and adolescent obesity [7]. It is universally accepted that obesity in children and adolescents is largely preventable, but a comprehensive understanding of its risk profiles is still necessary.

There is strong evidence that unhealthy lifestyle factors (ULFs) such as short sleep duration [8], fast food intake [9], sweet food intake [10], eating late [11, 12], and physical inactivity [13], are implicated in the development of childhood and adolescent obesity [14]. Thus far, the majority of observational studies have focused on one or more components of ULFs, and reports of ULFs as a whole are lacking. However, in reality, ULFs seldom occur in isolation but tend to co-exist, often in a synergistic manner. The effect of individual ULFs is small but can be enhanced pending the co-existence of others [15]. The co-existence of multiple types of ULFs might be strongly related to obesity compared to single ULFs. As such, deciphering the varying patterns of ULFs may offer insights into the complex relationship and potential mechanisms attributable to weight status disparities in children and adolescents.

To shed some light upon this issue, this study was aimed to test whether distinguishable clusters existed among Chinese children and adolescents with overweight or obesity by analyzing ULFs from seven dimensions via latent class analysis (LCA), and meanwhile to characterize between-cluster differences based on parental, fetal, and neonatal factors.

Methods

Study design

This study is ascribed to a continuously rolling project financed annually, which aims to monitor the growth and development status of children and adolescents in North China. Data from 3-year surveys were incorporated in this study. The first survey was performed in Beijing from September to November 2019, the second survey in Beijing and Tangshan from September to December 2020, and the third survey in January 2022 in Beijing.

Study participants

The questionnaire and selection process of study participants have been published previously [8, 9, 16]. Specifically, in the first survey, using a stratified cluster random sampling strategy, of 16 districts in Beijing, four were selected, and within each district, five public or private kindergartens were selected. In the second study, four of 16 districts in Beijing and two of seven districts in Tangshan were selected via the stratified and cluster sampling method; five kindergartens were selected from each district, and 30 kindergartens were included finally. In the third survey, children and adolescents attending eight primary schools and 18 junior high schools in Pinggu district, Beijing were recruited.

Data collection procedure

Data were collected through self-designed questionnaires, which were compiled as the QR codes by using the Wenjuanxing network platform (https://www.wenjuan.com/).

Items from survey questionnaires designed for children and adolescents, as well as for their parents, were incorporated. For children, items covered sex, age, height, weight, fetal and neonatal factors (gestational age, delivery mode, assisted reproduction, twin birth, and infancy feeding), lifestyle factors (weekly intake frequencies of sweet food, night meals, and fast food, eating speed, sedentary time, physical activity, and sleep duration). For parents, items covered self-reported age, height, and weight.

Overweight/obesity definition

Overweight and obesity are defined by body mass index (BMI), which is calculated as the ratio of weight (kg) to the square of body height (m). The criteria for defining overweight and obesity have been proposed by several official organizations, such as World Health Organization and International Obesity Task Force. Considering the dietary and cultural diversities across countries, the China criteria (WS/T 586–2018) for overweight/obesity definition were adopted in this study. In detail, overweight and obesity in children and adolescents are defined based on age- and sex-specific measurements.

Components of ULFs

Seven lifestyle factors were extracted to define ULFs, including fast food, sweet food, night meals intake frequency, eating speed, sedentary behavior, sleep duration, and physical activity. Each factor was categorically transformed.

Fast food referred to food with high energy and low nutrition, such as hamburger and pizza. Sweet food referred to food with sweet taste, such as bread cakes and desserts. Night meal referred to food eaten within

2 h before bedding. Weekly intake frequency of sweet food, fast food, and night meals were classified into two categories (none or once in a while and at least 1 time weekly). Eating speed was calculated as the average of breakfast, lunch, and dinner, and is divided into > 15 min and ≤ 15 min [17]. Sleep duration was classified into < 8 h and ≥ 8 h per day. Sedentary time (such as watching TV and playing computer games) and outdoor activity time recorded in hours were calculated as the sum of time spent on workdays × 5 and weekends × 2 divided by 7. In this survey, sedentary time was classified into ≤ 2 h and > 2 h per day. As recommended by the World Health Organization [18], physical activity was defined as engaging in any activity for at least 60 min per day, including running, walking, cycling, playing with friends, and dancing for children and adolescents.

Parental, fetal, and neonatal factors

Sex, age, fetal and neonatal factors (gestational age, delivery mode, assisted reproduction, twin birth, and infancy feeding), as well as parental age and overweight/obesity were recorded.

Statistical analyses

Categorical variables are presented as percentages and tested using either the χ [2] test or Fisher's exact test. Continuous variables are presented as means with standard deviations or medians with interquartile ranges, depending on their distributions, and differences were tested using either the Student's t-test or the Kruskal-Wallis test. Two-tailed *P*-value less than 0.05 was considered as statistically significant. Co-occurrences of ULFs were determined by counting the number of seven lifestyle factors under study.

LCA was used to characterize the potential patterns of ULF co-occurrence based on seven lifestyle factors (fast food, sweet food, night meals intake frequency and eating speed, sedentary behavior, sleep duration, and physical activity). With a set of categorical factor variables, LCA can assist in identifying subgroups within a population sharing similar patterns of ULFs. In this setting, LCA assigned participants into distinct and mutually exclusive clusters based on the model-based posterior membership probabilities [19]. Optimal number of clusters was determined after considering the Akaike's information criterion (AIC) and Bayesian information criteria (BIC) simultaneously. For each group number, LCA was implemented 10 times with random initial values, with AIC and BIC calculations each time. For group numbers ranging from 2 to 10, the cluster number with the lowest AIC and BIC was chosen. Moreover, an average posterior probability of assigning each participant to a group of approximately 70% or higher was indicative of a good fit, and models with greater than 5% membership in each cluster were selected.

Subsequently, multinomial logistic regression model was used to examine the association of fetal and neonatal factors with the optimal cluster of ULFs, with risk estimates expressed as odds ratio (OR) and its 95% confidence intervals (CI).

As missing rates of all assessed variables were under 5%, multiple imputation was used to fill in missing values through the "mice" order in R coding platform version 4.3.3 (R project for Statistical Computing) [20]. The LCA was run using the "poLCA" order in R coding platform. Unless otherwise stated, analyses were run in STATA software version 14.0 (Stata Corp, College Station, TX, United States).

Ethics statement

The first two surveys were approved by the Ethics Committee of China-Japan Friendship Hospital, and the third survey by the Ethics Committees of Beijing University of Chinese Medicine, in compliance with the principles of the Declaration of Helsinki. The privacy of personal information was protected throughout the study via anonymous data collection, and confidentiality was maintained by asking participants to provide honest answers.

Results

Participant characteristics

Data from three surveys were pooled together after strictly reviewing the validity of survey data. Total 7,321 questionnaires were deemed eligible for the first survey, and 8,297 questionnaires for the second survey, and 10,206 questionnaires for the third survey. Finally, 7,927 children and adolescents with overweight or obesity were included in the analysis. The baseline characteristics of study participants are shown in Table 1.

There was a slightly higher proportion of boys *vis-à-vis* girls (56.14% vs. 43.86%). 3,938 (49.68%) children and adolescents were overweight, with median age of 7 years (interquartile range [IQR] 4.8–10.7). Of 7,927 study participants, 7,627 (96.78%) had at least one ULF, and 6,942 (87.57%) had two or more ULFs concurrently.

Cluster determination and characterization

After comparing the performance of 1 to 10 numbers of clusters derived from LCA, four distinct clusters at the elbow point proved to be optimal (eTable 1), and subgroup analyses based on age classification standards for children (3–6, 7–12, > 12 years) are shown in eTable 2.

The distributions of ULFs across four clusters are exhibited in Table 2, and they differed significantly. There were 3,069, 2,186, 1,846, and 826 participants in Cluster I, Cluster II, Cluster III, and Cluster IV, respectively. Cluster I was characterized by the "unhealthy food intake but

Table 1 The baseline characteristics of study children and adolescents by gender

Variables		All participants (N = 7,927)	Boys (N = 4,450)	Girls (N = 3,477)	*P*
Age (Median [IQR])		7.00 [4.80, 10.70]	7.75 [4.90, 11.00]	6.10 [4.70, 10.10]	< 0.001
Survey waves	2019	1,781 (22.5)	902 (25.9)	879 (19.8)	< 0.001
	2020	2,024 (25.5)	958 (27.6)	1,066 (24.0)	
	2022	4,122 (52.0)	1,617 (46.5)	2,505 (56.3)	
Paternal age (Median [IQR])		37.00 [34.00, 40.00]	37.00 [34.00, 40.00]	36.94 [34.00, 40.00]	< 0.001
Maternal age (Median [IQR])		36.00 [33.00, 39.00]	36.00 [33.00, 39.00]	35.34 [33.00, 38.69]	0.002
Delivery mode (%)	Vaginal delivery	3,720 (46.9)	2,003 (45.0)	1,717 (49.4)	< 0.001
	Cesarean section	4,207 (53.1)	2,447 (55.0)	1,760 (50.6)	
Assisted reproduction (%)	No	7,792 (98.3)	4,372 (98.2)	3,420 (98.4)	0.764
	Yes	135 (1.7)	78 (1.8)	57 (1.6)	
Twins (%)	No	7,746 (97.7)	4,354 (97.8)	3,392 (97.6)	0.439
	Yes	181 (2.3)	96 (2.2)	85 (2.4)	
Infancy feeding (%)	Pure breastfeeding	4,495 (56.7)	2,459 (55.3)	2,036 (58.6)	0.012
	Partial breastfeeding	2,710 (34.2)	1,566 (35.2)	1,144 (32.9)	
	Non-breastfeeding	722 (9.1)	425 (9.6)	297 (8.5)	
Full-term birth (%)	Yes	7,114 (89.7)	3,994 (89.8)	3,120 (89.7)	1.000
	No	813 (10.3)	456 (10.2)	357 (10.3)	
Maternal overweight/obesity (%)	No	4,451 (57.0)	2,518 (57.4)	1,933 (56.3)	0.337
	Yes	3,363 (43.0)	1,865 (42.6)	1,498 (43.7)	
Paternal overweight/obesity (%)	No	1,910 (24.2)	1,060 (23.9)	850 (24.6)	0.496
	Yes	5,989 (75.8)	3,379 (76.1)	2,610 (75.4)	
Fast food intake frequency (%)	None or once in a while	3,972 (50.1)	2,075 (46.6)	1,897 (54.6)	< 0.001
	At least 1 time weekly	3,955 (49.9)	2,375 (53.4)	1,580 (45.4)	
Sweet food intake frequency (%)	None or once in a while	3,543 (44.7)	1,906 (42.8)	1,637 (47.1)	< 0.001
	At least 1 time weekly	4,384 (55.3)	2,544 (57.2)	1,840 (52.9)	
Night meals intake frequency (%)	None or once in a while	3,871 (48.8)	2,037 (45.8)	1,834 (52.7)	< 0.001
	At least 1 time weekly	4,056 (51.2)	2,413 (54.2)	1,643 (47.3)	
Eating speed (minutes) (%)	≥ 15	4,179 (52.7)	2,428 (54.6)	1,751 (50.4)	< 0.001
	< 15	3,748 (47.3)	2,022 (45.4)	1,726 (49.6)	
Sleep duration (hours per day) (%)	≥ 8	5,577 (70.4)	3,252 (73.1)	2,325 (66.9)	< 0.001
	< 8	2,350 (29.6)	1,198 (26.9)	1,152 (33.1)	
Sedentary time (hours per day) (%)	≤ 2	1,857 (23.4)	1,043 (23.4)	814 (23.4)	0.999
	> 2	6,070 (76.6)	3,407 (76.6)	2,663 (76.6)	
Physical activities (hours per day) (%)	Yes	5,025 (63.4)	2,932 (65.9)	2,093 (60.2)	< 0.001
	No	2,902 (36.6)	1,518 (34.1)	1,384 (39.8)	
Number of co-occurrences					
	0	255 (3.2)	129 (2.9)	126 (3.6)	0.104
	1	730 (9.2)	423 (9.5)	307 (8.8)	
	2	991 (12.5)	557 (12.5)	434 (12.5)	
	3	1,693 (21.4)	915 (20.6)	778 (22.4)	
	4	2,174 (27.4)	1,236 (27.8)	938 (27.0)	
	5	1,568 (19.8)	913 (20.5)	655 (18.8)	
	6	474 (6.0)	253 (5.7)	221 (6.4)	
	7	42 (0.5)	24 (0.5)	18 (0.5)	

Data are presented as number (percentage) or median (interquartile range [IQR]). Number of co-occurrences was added by the existence of seven lifestyle factors under study

long sleeping", with 96.3%, 94.3%, and 98.3% participants having high frequencies (at least 1 time weekly) of consuming fast food, sweet food, and night meals, and with 97.0% participants having sleeping time ≥ 8 h per day.

Cluster II was regarded as the "relative health", with 95.5%, 75.6%, 84.5% participants having low frequencies (none or once in a while) of consuming fast food, sweet food, and night meals, with 72.2% having long eating time (≥ 15 min), with 93.0% having long sleep time (≥ 8 h per day), and with 70.7% being physically active.

Cluster III was characterized by the "healthy food intake but unhealthy eating-sleeping-sitting habits", with

Table 2 Distribution of unhealthy lifestyle factors (ULFs) based on four clusters.

ULFs	Categories	Cluster I	Cluster II	Cluster III	Cluster IV	P
Fast food intake frequency (%)	None or once in a while	114 (3.7)	2,087 (95.5)	1,771 (95.9)	0 (0.0)	< 0.001
	At least 1 time weekly	2,955 (96.3)	99 (4.5)	75 (4.1)	826 (100.0)	
Sweet food intake frequency (%)	None or once in a while	176 (5.7)	1,652 (75.6)	1,324 (71.7)	391 (47.3)	< 0.001
	At least 1 time weekly	2,893 (94.3)	534 (24.4)	522 (28.3)	435 (52.7)	
Night meal intake frequency (%)	None or once in a while	52 (1.7)	1,847 (84.5)	1,578 (85.5)	394 (47.7)	< 0.001
	At least 1 time weekly	3,017 (98.3)	339 (15.5)	268 (14.5)	432 (52.3)	
Eating speed (minutes) (%)	≥ 15	2,152 (70.1)	1,579 (72.2)	0 (0.0)	448 (54.2)	< 0.001
	< 15	917 (29.9)	607 (27.8)	1,846 (100.0)	378 (45.8)	
Sleep duration (hours per day) (%)	≥ 8	2,976 (97.0)	2,034 (93.0)	0 (0.0)	567 (68.6)	< 0.001
	< 8	93 (3.0)	152 (7.0)	1,846 (100.0)	259 (31.4)	
Sedentary time (hours per day) (%)	≤ 2	625 (20.4)	978 (44.7)	249 (13.5)	5 (0.6)	< 0.001
	> 2	2,444 (79.6)	1,208 (55.3)	1,597 (86.5)	821 (99.4)	
Physical activity (hours per day) (%)	Yes	1,826 (59.5)	1,545 (70.7)	1,354 (73.3)	300 (36.3)	< 0.001
	No	1,243 (40.5)	641 (29.3)	492 (26.7)	526 (63.7)	

Table 3 Association of parental, fetal, and neonatal factors with the "unhealthy" cluster groups.

Risk factor		Cluster I vs. Cluster II	Cluster III vs. Cluster II	Cluster IV vs. Cluster II
Age		2.021*** (1.953, 2.091)	0.655*** (0.624, 0.687)	2.181*** (2.090, 2.276)
Sex	Boys	Ref.	Ref.	Ref.
	Girls	0.765*** (0.684, 0.855)	1.231** (1.087, 1.394)	0.994 (0.846, 1.167)
Delivery mode	Vaginal delivery	Ref.	Ref.	Ref.
	Cesarean section	1.178** (1.055, 1.315)	0.686*** (0.606, 0.777)	1.208* (1.028, 1.420)
Assisted reproduction	No	Ref.	Ref.	Ref.
	Yes	0.550** (0.360, 0.839)	0.634 (0.395, 1.017)	1.006 (0.589, 1.716)
Twins	No	Ref.	Ref.	Ref.
	Yes	0.902 (0.624, 1.303)	1.096 (0.736, 1.630)	0.759 (0.425, 1.356)
Infancy feeding	Pure breastfeeding	Ref.	Ref.	Ref.
	Partial breastfeeding	0.783*** (0.696, 0.880)	0.718*** (0.628, 0.820)	0.767** (0.644, 0.913)
	Non-breastfeeding	1.331** (1.087, 1.628)	0.884 (0.695, 1.124)	1.410* (1.070, 1.858)
Full-term birth	Yes	Ref.	Ref.	Ref.
	No	1.034 (0.865, 1.237)	0.891 (0.723, 1.098)	1.034 (0.797, 1.342)
Maternal age		1.187*** (1.170, 1.205)	1.006 (0.990, 1.022)	1.197*** (1.173, 1.221)
Paternal age		1.157*** (1.142, 1.173)	1.028*** (1.013, 1.044)	1.173*** (1.152, 1.194)
Maternal overweight/obesity	No	Ref.	Ref.	Ref.
	Yes	1.360*** (1.217, 1.520)	0.602*** (0.529, 0.687)	1.499*** (1.273, 1.763)
Paternal overweight/obesity	No	Ref.	Ref.	Ref.
	Yes	1.535*** (1.349, 1.747)	0.909 (0.793, 1.043)	1.673*** (1.371, 2.042)

Abbreviations: Ref., reference group

Data are expressed as odds ratio (95% confidence interval)

Multinomial logistic regression model for the association of fetal and neonatal factors with the membership to unhealthy lifestyle factors

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

95.9%, 71.7%, and 85.5% participants having low frequencies (none or once in a while) of consuming fast food, sweet food, and night meals, with 100% eating fast (< 15 min), 100% sleeping less than 8 h per day, and 86.5% spending sedentary time over 2 h per day.

Cluster IV was characterized by the "unhealthy food intake and unhealthy sitting-activity habits", with 100% participants having high fast food intake frequency, 99.4% spending sedentary time over 2 h per day, and 63.7% being physically inactive.

Risk profiles of clusters

Table 3 shows the association of parental, fetal, and neonatal factors with the "unhealthy" cluster groups after assigning Cluster II as the reference group. In multinomial logistic regression analyses, for the comparison of Cluster I with Cluster II, child age, cesarean delivery mode, no breastfeeding, parental age, and overweight/obesity were significant risk factors, with OR ranging from 1.157 to 2.021, yet female sex, partial breastfeeding, and assisted reproduction were significant protective factors (OR: 0.765, 0.783, and 0.550; 95% CI: 0.684 to

0.855, 0.696 to 0.880, and 0.360 to 0.839, respectively, all $p < 0.01$).

Comparing Cluster III with Cluster II yielded increased risk for female sex (OR, 95% CI: 1.231, 1.087 to 1.394) and paternal age (1.028, 1.013 to 1.044), but decreased risk for child age (0.655, 0.624 to 0.687), cesarean delivery mode (0.686, 0.606 to 0.777), partial breastfeeding (0.718, 0.628 to 0.820), and maternal overweight/obesity (0.602, 0.529 to 0.687) (all $p < 0.01$).

Relative to Cluster II, child age (OR, 95% CI: 2.181, 2.090 to 2.276), cesarean delivery mode (1.208, 1.028 to 1.420), no breastfeeding (1.410, 1.070 to 1.858), parental age (mum and dad: 1.197 and 1.173, 1.173 to 1.221 and 1.152 to 1.194) and overweight/obesity (mum and dad: 1.499 and 1.673, 1.273 to 1.763 and 1.371 to 2.042) were associated with the significantly increased risk of Cluster IV, while partial breastfeeding was associated with the reduced risk (all $p < 0.05$).

Discussion

As an extension of our prior serial surveys, we pooled data from children and adolescents aged 3–14 years with overweight or obesity, and attempted to test whether there were distinguishable clusters based on seven dimensional ULFs. It is worth noting that over 95% of children and adolescents had at least one ULF, and nearly 85% had two or more ULFs. Importantly, four clusters outperformed from one to 10 numbers of clusters, and they can be classified into the "unhealthy food intake but long sleeping", "relative health", "healthy food intake but unhealthy eating-sleeping-sitting habits", and "unhealthy food intake and unhealthy sitting-activity habits" groups. Risk profiles associated with the "unhealthy" clusters differed obviously, which reinforced the rationale of clustering. To our knowledge, this is to date the first report that has deciphered the potential clustering of seven-dimension ULFs in children and adolescents with overweight or obesity.

In the literature, LCA has been widely adopted to determine the optimal clusters or patterns of diets, physical activity, and sedentary behaviors among children, adolescents, and young adults [21, 22]. However, no studies have examined the clusters of multiple lifestyle factors that simultaneously consider food source, eating habit, sleeping duration, sedentary behavior, and physical activity. The rationale behind seeking the clusters of children and adolescents with overweight or obesity is that their lifestyle habits and behaviors are multifaceted and interactive per se. The importance of clustering can group obesogenic behaviors and assist in the development of initiatives to prevent unhealthy weight and its comorbidities.

In this study, the majority of children and adolescents can be grouped as the "unhealthy food intake but long sleeping" cluster, which can reflect the rapid pace of modern life in China. Over the last decade, ordering take-outs online has already become a kind of normality for the majority of young people owing to its convenience. Most of take-out food is high in oil, fat, and salt, and has less vegetables and more meat. Unhealthy food intake is common in children and adolescents, and is a major risk factor for various health problems, including overweight and obesity. The iResearch statistics indicated that of 900 million Internet users in China, there were about 460 million ordering take-outs in 2019 [23]. To curb this unhealthy lifestyle, reducing the frequency of eating fast food, sweet food, and night meals might be an effective strategy to curb the occurrence and progression of obesity in children and adolescents in China.

Moreover, another distinct cluster included children and adolescents with healthy food intake but unhealthy eating-sleeping-sitting habits (Cluster III), which reflects the problems of habitual behaviors. Eating, sleeping, and playing are three important parts of child daily life. According to our prior reports [24], late bedtime and fast eating speed were found to interact synergistically in predisposition to overweight and obesity in preschool-aged children. The impact of fast eating speed on overweight and obesity in children is probably attributed to higher energy intake due to the interference of gastrointestinal hormones, such as ghrelin suppression [25, 26]. Slow eating rate can be accomplished with greater fullness, greater ghrelin suppression post-meal, and less energy from snacks, and thus significantly impact gastrointestinal hormone response to a carbohydrate in retraining obese adolescents [27, 28]. As an extension of prior observations, we, in the present study, found that eating fast, sleeping less, and playing less often co-occur and interplay, and the proportion of unhealthy eating-sleeping-sitting habits existed among 23.3% of children and adolescents with overweight or obesity. Hence, how to improve unhealthy eating-sleeping-sitting habits might be a solution to impede the rising prevalence of childhood and adolescent obesity.

Another small cluster, "unhealthy food intake and unhealthy sitting-activity habits", accounting for about 10% of children and adolescents with overweight or obesity, also merits consideration. Besides unhealthy food intake as discussed above, less movement is more common, especially among school-aged children and adolescents. In China, students' overweight and obesity burden can reflect, at least partly, the heavier workload in schools, leaving more time for sedentary behavior and less time for outside physical activity. Findings from a Chinese national follow-up study revealed that children and adolescents experiencing an unfavorable school physical activity environment had a higher incidence of comorbid obesity compared to a favorable school

environment, emphasizing the importance of creating a favorable school physical activity environment [29]. Soares et al. have written an excellent review on the impact of physical activity on body mass and composition of school-age children and adolescents with overweight or obesity, and found that recreational and systematized physical activity may improve body mass, particularly body composition [30]. Above lines of evidence collectively enlightens endeavors for health and healthcare workers to carry out targeted primary and secondary preventive strategies in the future.

Besides the differing emphases, the four clusters based on seven-dimension ULFs characterized in this study has proven to be reasonable, as the risk profiles differed remarkably across clusters. For example, in clusters characterized by "unhealthy food intake" (Cluster I and Cluster IV), parental age and overweight/obesity were identified as risk factors relative to children and adolescents in Cluster II, but remained nonsignificant and even protective in clusters characterized by "healthy food intake." Considering the complexity of childhood and adolescent obesity, our preliminary clustering results should be deemed as hypothesis-generating, and we agree that further large-scale, longitudinal studies are necessary to confirm our findings.

Finally, some limitations should be acknowledged. First, due to the cross-sectional design, it was impossible to determine the causal direction of association between ULFs and overweight or obesity in children and adolescents. Second, this study relied on self-reported lifestyle factors, which may be subject to social desirability bias. Third, although a wide panel of lifestyle factors were considered, more are needed to provide a clear picture. Fourth, all children and adolescents are of Chinese descent, and external replication of our findings is needed.

Conclusions

Despite above limitations, our findings indicate that ULFs are extremely common in Chinese children and adolescents with overweight or obesity, who can be classified into four distinct clusters. For practical reasons, identifying distinct patterns of ULFs can help researchers better understand the etiological factors of overweight and obesity among children and adolescents and has important implications for health promotion and public health.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12887-025-05567-y.

Supplementary Material 1

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Author contributions

Z.Z. and W.N. planned and designed the study and directed its implementation; Z.Z. and W.N. drafted the protocol; Q.W. and M.Y. obtained statutory and ethics approvals; Q.W. and M.Y. contributed to data acquisition; Q.W., F.Z. and K.C. conducted statistical analyses; K.C. and F.Z. did the data preparation and quality control; Q.W. and W.N. wrote the manuscript. All authors read and approved the final manuscript prior to submission. The corresponding author (W.N.) attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Data availability

The 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

The first two surveys were approved by the Ethics Committee of China-Japan Friendship Hospital, and the third survey by the Ethics Committees of Beijing University of Chinese Medicine, in compliance with the principles of the Declaration of Helsinki. The privacy of personal information was protected throughout the study via anonymous data collection, and confidentiality was maintained by asking participants to provide honest answers. Informed consent to participate has been obtained from the parents or legal guardians of any participants under the age of 16.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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