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Appetitive traits and body mass index in Chinese adolescents: An 18-month longitudinal study with latent growth curve analyses

Yawei Cheng [a], Wesley R. Barnhart [b], Guangsheng Liang [c], Gui Chen [d], Tom Lu [a,*], Jinbo He [e,**]

[a] Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, United States of America
[b] Department of Psychology, Bowling Green State University, Bowling Green, OH, United States of America
[c] Department of Psychological Sciences, Texas Tech University, Lubbock, TX 79409, United States of America
[d] College of Educational Science, Hengyang Normal University, Hengyang, Hunan, China
[e] School of Humanities and Social Science, The Chinese University of Hong Kong, Shenzhen, Guangdong, China

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ABSTRACT

A longitudinal approach with Latent Growth Curve Modeling (LGCM) was adopted to explore the trajectories of appetitive traits corresponding to BMI in Chinese adolescents. Within a large sample of adolescents ($N = 2566$, 45.9% boys) aged from 11 to 17 years ($M = 13.80$, $SD = 1.56$) at the baseline survey, our results indicated that appetitive traits of emotional overeating, food fussiness, and hunger increased significantly over time while enjoyment of food decreased over time. Slowness in eating and satiety responsiveness significantly increased in girls, while emotional undereating significantly decreased in boys. Moreover, the growth parameters of emotional undereating and satiety responsiveness were significantly and negatively related to BMI in girls. Our findings evidence that certain appetitive traits could change over time in adolescence and these changes relate to weight status. Gender differences are suggested in the design of future intervention and treatment of overweight/obesity in Chinese adolescents.

1. Introduction

Overweight and obesity have become a worldwide public health problem [1], including China. According to the Chinese National Survey of Students' Constitution and Health (CNSSCH), the prevalence of overweight and obesity among children and adolescents increased from 1.3% in 1985 to 19.4% in 2014 [2]. Importantly, the increased prevalence of overweight/obesity also corresponds to increased health complications that negatively impact health and health systems. Additionally, children with obesity have a high likelihood of being obese in adulthood [3]. Thus, there is a continued need to adopt a pediatric approach to achieving a healthy weight status given its potential to improve health in adulthood.

The causes of obesity are linked to genetic, environmental, and behavioral factors [4–6]. For example, among the behavioral factors, increased consumption of foods that are high in fats and calories are known antecedents to the development of an elevated weight status [7]. These behaviors receive influences from appetitive traits [8–11] which play an important role in determining an individual's susceptibility toward foods, including healthy and unhealthy foods. Furthermore, bidirectional relationships between appetitive behaviors and body mass index were also found in a Norwegian cohort study such that an increased food response at age 6 predicted more rapid weight gain at age 8, and BMI at age 4 predicted higher levels of food responsiveness and reduced satiety responsiveness at age 6 [12]. Specifically, appetitive traits are a set of persistent predispositions toward food [13]. They could be broadly classified into two groups based on appetitive responsiveness to food cues: food avoidance (poor appetite for food) and food approach (greater appetite for food) appetitive traits. Food avoidance traits are related to lower BMI while food approach traits are related to higher BMI [14]. Importantly, appetitive traits can be individually dependent [4,15], which can be affected by internal stimuli (e.g., physiological hunger/satiety [16] and negative affect [17]) and external stimuli (e.g., parental feeding styles [18,19] and properties of food [20]).

Prior research has established the relationship between appetitive traits and overweight/obesity in children and adolescents. For instance, children with an overweight weight status eat more in response to food cues (high food responsiveness [21]), and have a faster rate of eating

* Corresponding authors.
** Correspondence to: Department of Mathematics and Statistics, Texas Tech University, Lubbock, Texas, 79409, United States (Tom Lu); School of Humanities and Social Science, Chinese University of Hong Kong, Shenzhen 518172, Guangdong, China (Jinbo He).
E-mail addresses: t.lu@ttu.edu (T. Lu), anlfhe@gmail.com (J. He).

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(low slowness in eating [22]) than those with a healthy weight status. They also have lower scores in emotional under-eating compared to children with a healthy weight status [13]. In contrast, children with higher scores on food avoidance traits are less likely to overeat and have lower weight statuses [23–25]. Relatedly, adolescents with an overweight weight status consumed more food with absolute calories and energy requirements than those with a healthy weight status, and consuming more food can be treated as a signal of low sensitivity to satiety [26]. Moreover, adolescents with obesity reported no dislike for food (low food fussiness [27]), while fussiness about eating was linked to a lower likelihood of having an overweight or obese weight status [28]. Furthermore, gender differences in appetitive traits have been found in previous studies. For instance, girls had greater enjoyment of food and lower emotional overeating and fussy eating than boys in a cohort of Dutch children [29]. Moreover, in a sample of Chinese children, girls had greater enjoyment of food, satiety responsiveness, and slowness in eating than boys [30].

In the present study, we aim to further investigate this association with a longitudinal research design since the bulk of the research has used cross-sectional designs [31,32]. Such cross-sectional designs leave unclear the temporal nature of relationships between appetitive traits and weight status. Moreover, even though there were previous studies that used longitudinal designs and/or revealed the reciprocal associations between appetitive traits and BMI [33–36], these studies mostly focus on children rather than adolescents. Furthermore, prior research has mainly investigated relationships between appetitive traits and weight status in developed countries such as Norway [37], UK [31], USA [38], and Australia [39]; however, little research has been conducted from the perspective of developing countries (e.g., China [40]). Here, we aimed to explore (1) the trajectories of appetitive traits in Chinese adolescents, and (2) the extent to which the changes in appetitive traits might explain changes in BMI over 18 months (4 waves, 6-month intervals). In addition, as gender differences have been reported in appetitive traits, as well as within associations between appetitive traits and BMI [15,41], we explored the presence of gender differences across relationships. Based on the existing literature, we hypothesized that appetitive traits would change over time, with the baseline level and rate of changes in food avoidance appetitive traits being negatively related to BMI, and the baseline level and rate of changes in food approach appetitive traits being positively related to BMI among Chinese adolescents.

2. Method

2.1. Participants and procedure

The data used in the present study were self-reported from a large-scale longitudinal project about body image, eating behaviors, and media among Chinese adolescents [42]. These longitudinal data were collected across four waves at 6-months intervals. The project was approved by the research ethics office of Hengyang Normal University. Specifically, the data were collected at one junior high school and one senior high school from the same city in Hunan Province. We first received permission from the two schools to carry out the project. Next, the project was introduced to the students during class. If students agreed to participate, a consent form was requested from their parents or other custodians (e.g., grandparents) indicating their approval. Fig. 1 shows the number of participants in this longitudinal project at each wave. Initially, 2976 students from the two schools were invited to participate in the project, which included four waves of data collection. However, 263 students were removed from participation because they either refused the invitation or failed to obtain parental or legal guardian approval. As a result, 2713 students were involved at baseline and follow-ups in this longitudinal study. To ensure the survey quality, at each assessment of the four-wave data collection, we removed the surveys from students that were determined to be invalid (i.e., failing to pass the attention checks) or incomplete (failing to complete at least 50% of the questionnaires in a survey). Moreover, as the present study adopted a longitudinal study design, in line with previous studies [43–45], only adolescents that participated in at least two waves of data collection were included in the final analyses. Thus, a total of 2566 adolescents were included in the data analyses. Specifically, 2086 adolescents (44.9% boys) aged from 11 to 17 years were retained in the baseline data collection. Furthermore, 1909 (43.8% boys), 2023 (43.8% boys), and 1947 (42.5% boys) were retained in the second (6-months), third (12-months), and fourth (18-months) waves of data collection.

3. Measures

3.1. Appetitive traits

To measure appetitive traits in adolescents, we employed the Chinese version of the Adult Eating Behavior Questionnaire [40]. The AEBQ is a 35-item self-report scale that evaluates adults' appetitive

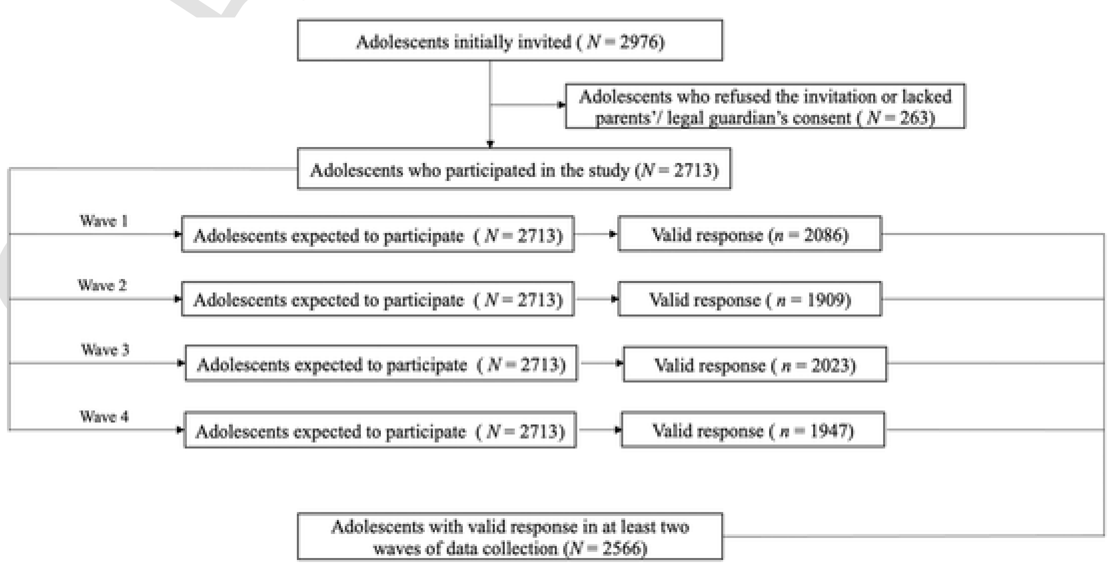

Fig. 1. Flow chart of sampling of participants in the present study.

traits. Each item is given a five-point Likert rating, ranging from strongly disagree to strongly agree [46]. It consists of 4 food approach traits [Food Responsiveness (FR, four items, e.g., "*when I see or smell food that I like, it makes me want to eat*"), Emotional Overeating (EOE, five items, e.g., "*I eat more when I'm anxious*"), Hunger (H, five items, e.g., "*I often feel so hungry that I have to eat something right away*"), and Enjoyment of Food (EF, three items, e.g., "*I love food* ")], and 4 food-avoidance traits [Emotional Undereating (EUE, five items, e.g., "*I eat less when I'm worried* "), Satiety Responsiveness (SR, four items, e.g., "*I often leave food on my plate at the end of a meal*"), Slowness in Eating (SE, four items, e.g., "*I am often last at finishing a meal*"), and Food Fussiness (FF, five items, e.g., "*I refuse new foods at first*")]. The AEBQ has shown good internal consistency reliability and convergent validity when used with adolescents [47,48]. Furthermore, previous research has demonstrated that the AEBQ can be used as a sound measure of appetitive traits in Chinese young adults [40].

3.2. Overweight and obesity

Participants' weight and height were self-reported. Weight was reported in kilograms and height was reported in centimeters. These data were used to calculate BMI. Then, According to Zong and Li [49], the BMI z-scores were calculated.

3.3. Statistical analysis

Mplus version 8.1 was used for data analyses. First, descriptive statistics were calculated. McDonald's omega was used to measure the internal consistency reliability [50]. Then, the bivariate Pearson's correlations between appetitive traits and BMI z-scores were calculated to evaluate the relationships between appetitive traits and BMI z-scores. Next, to obtain the trajectory of appetitive traits by gender, each appetitive trait assessed over 18 months was investigated by gender using latent growth curve modeling (LGCM), an effective approach for analyzing differences in individual developmental trends and further understanding the developmental characteristics of different groups [51]. In this analysis, an unconditional LGCM was first fitted for each appetitive trait. In the unconditional LGCM, there were two latent parameters included: the intercept (i.e., mean beginning level) and the slope (i.e., the average rate of change over time). Furthermore, the variation of the intercept and slope was also obtained. In each wave, the intercept factors were set to 1.0 to represent the baseline level of each appetitive trait. The slope factors were kept constant throughout the four waves, ranging from 0 to 3. Next, to predict the latent growth factors of BMI by gender, a parallel LGCM was fitted by using the latent growth factors of each appetitive trait for both boys and girls (see Fig. 2). This method makes it possible to vary the linear relationship between appetitive traits and BMI-z scores in both slope and intercept between individuals [52]. When running the models, the impact of participants' age was controlled. Through this approach, a number of specific effects were estimated: 1) the effects of appetitive trait intercepts on the BMI-z scores intercept; 2) the effects of appetitive trait intercepts on the slope of BMI-z scores over 18 months; 3) the effects of the slopes of appetitive traits on the slope of BMI-z scores over 18 months; 4) the correlation between the intercept of each appetitive trait and the slope of each appetitive trait over 18 months; and 5) the correlation between the intercept of BMI-z scores and the slope of BMI-z scores over 18 months.

For all models, the goodness fit of the model was evaluated by using comparative fit index (CFI), Turker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). Based on the recommendations of Hu and Bentler [53], model fit was good when CFI $\geq$ .95, TLI $\geq$ .95, RMSEA $\leq$ .06, SRMR $\leq$.06, and p values $<$ 0.05 was deemed to be statistically significant.

In terms of missing data, 0.18% of the items in the dataset at all four timepoints were missing. Little's (1988) missing totally at random test (MCAR) was used to detect the missing pattern and showed a result of not completely missing random test ($\chi^2 = 85, p<.001$). As a result, according to Lee and Shi [54], the full information maximum likelihood method was used automatically to deal with missing data in Mplus [55].

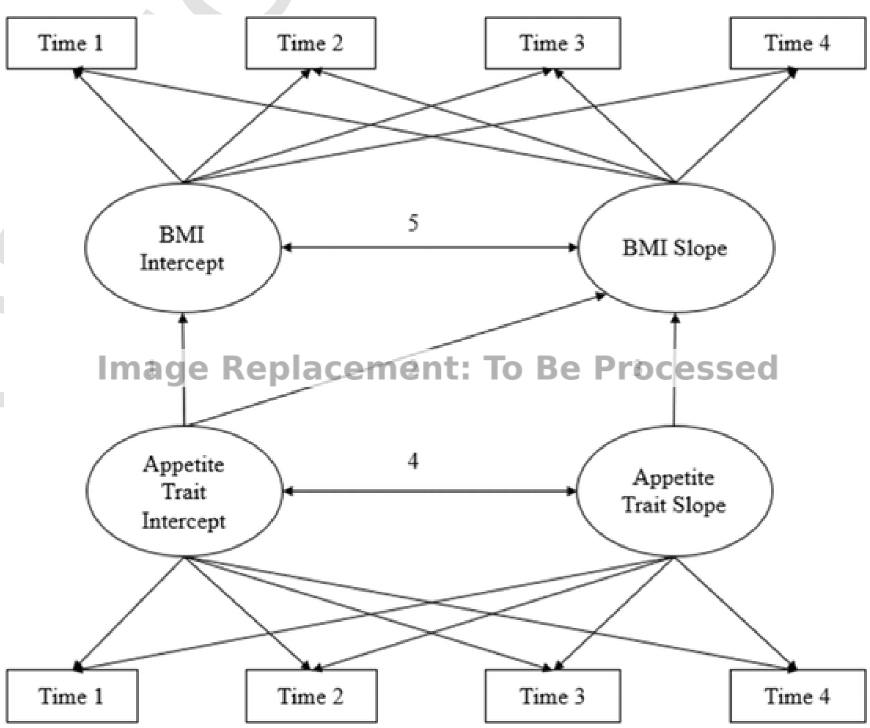

Fig. 2. A schematic diagram depicting the parallel latent growth curve model.

4. Results

4.1. Descriptive statistics

Table 1 presents descriptive statistics (mean, standard deviation, and McDonald's omega). The correlations of appetitive traits and BMI z-scores, with the corresponding *p*-values in the four waves of data collection, are shown in Table S1.

4.2. Unconditional LGCMs for appetitive traits

Table 2 shows the model fit indices of each appetitive trait by gender. Unconditional LGCMs were fitted to all appetitive traits to obtain the trajectory of appetitive traits. As shown in Table 2, the model fit of results showed that all models fitted the data well (i.e., CFI ≥ 0.95, TLI ≥ 0.95, and RMSEA ≤ 0.06).

Table 1
Descriptive statistics of the dataset.

	Wave 1	Wave 2	Wave 3	Wave 4
	Mean (SD)/ Omega	Mean (SD)/ Omega	Mean (SD)/ Omega	Mean (SD)/Omega
Age	13.903 (1.519)	14.460 (1.584)	14.948 (1.525)	15.412 (2.499)
BMI-z	-0.071 (0.994)	-0.022 (1.025)	-0.053 (0.988)	0.074 (0.969)
EF	3.995 (0.804) / 0.817	3.881 (0.864) / 0.856	3.865 (0.860) / 0.858	3.747 (0.845) / 0.875
EOE	2.268 (1.066) / 0.941	2.295 (1.000) / 0.943	2.401 (1.015) / 0.947	2.416 (0.976) / 0.953
FR	2.825 (0.887) / 0.757	2.751 (0.880) / 0.775	2.803 (0.874) / 0.780	2.798 (0.828) / 0.780
H	2.368 (0.843) / 0.812	2.365 (0.866) / 0.843	2.420 (0.864) / 0.854	2.480 (0.839) / 0.866
FF	2.438 (0.734) / 0.690	2.496 (0.731) / 0.718	2.563 (0.701) / 0.711	2.622 (0.677) / 0.707
EUE	2.835 (1.194) / 0.965	2.830 (1.168) / 0.969	2.748 (1.115) / 0.974	2.746 (1.067) / 0.974
SE	2.337 (0.861) / 0.805	2.421 (0.833) / 0.784	2.406 (0.826) / 0.787	2.505 (0.781) / 0.789
SR	2.591 (0.813) / 0.693	2.668 (0.874) / 0.756	2.681 (0.865) / 0.773	2.728 (0.852) / 0.813

Notes: EF = Enjoyment of Food, EOE = Emotional Overeating, FF = Food Fussiness, EUE = Emotional Undereating, FR = Food Fussiness, H = Hunger, SE = Slowness in Eating, SR = Satiety Responsiveness

The parameter estimates for unconditional LGCM of appetitive traits are presented in Table 3. For EF, significant negative slopes were found for boys and girls, suggesting both boys' and girls' EF decreased over the 18-months study period. However, significant positive slopes were found for boys and girls for EOE, FF, and H, indicating both boys' and girls' EOE, FF, and H increased over the 18-months study period. For EUE, boys had a significant negative slope, but the slope for girls was not significant, indicating that only boys' EUE decreased over the 18-month study period. For SE and SR, girls had a significant positive slope, while the slope for boy's was not significant, suggesting that only girls' SE and SR increased over the 18-month study period. However, for FR, the slopes for both boys' and girls' models were not statistically significant, suggesting that FR did not change over the 18-month study period across both genders.

In addition, except for EOE for girls and EUE for boys, correlations between the intercept and slope were negative and significant for all appetitive traits, suggesting that a higher baseline level of appetitive traits tended to observe a slower change in appetitive traits over time in both boys and girls.

4.3. Parallel LGCMs for the relationships between appetitive traits and BMI-z scores

Regarding the second goal of the study, parallel LGCMs were used to explore the longitudinal relationships between appetitive traits and BMI-z scores, and all parallel LGCMs showed satisfactory model fit (Table 1). Table 4 shows the parameter estimates and confidence intervals for the associations between appetitive traits and BMI-z scores.

Specifically, for EF, EOE, and FR, the growth parameters (i.e., intercept and slope) could not predict the slopes of BMI-z scores in both boys and girls. For FF, the intercept was negatively correlated with the slope of BMI-z scores in boys, while the intercept and slope could not predict the slopes of BMI-z scores in girls, indicating higher baseline FF related to lower growth rate of BMI-z scores in boys. The slopes of BMI-z scores were significantly negatively correlated with the intercepts and slopes for EUE and SR for girls, while not significant for boys, suggesting that higher baseline and growth rate of EUE and SR related to lower growth rate of BMI-z scores in girls. For H, the slope was negatively correlated with the slope of BMI-z scores in boys, while the intercept was negatively correlated with the slope of BMI-z scores in girls, indicating higher growth rate of H related to lower growth rate of BMI-z scores in boys, and higher baseline H for girls related to lower growth rate of BMI-z scores in girls. Finally, for SE, the slope of BMI-z scores was sig-

Table 2
Model fit of the latent growth curve models for each appetitive trait by gender.

Appetitive Traits			Unconditional LGCM					Parallel LGCM				
Food Approach Traits			χ^2/df	RMSEA (90% CI)	CFI	TLI	SRMR	χ^2/df	RMSEA (90% CI)	CFI	TLI	SRMR
	EF	Boys	2.28	0.03 (0.01–0.06)	0.98	0.98	0.06	1.74	0.03 (0.01–0.04)	0.99	0.98	0.03
		Girls	3.07	0.04 (0.02–0.06)	0.98	0.98	0.05	3.12	0.04 (0.03–0.05)	0.97	0.97	0.03
	EOE	Boys	0.56	0 (0–0.03)	1.00	1.01	0.01	1.8	0.03 (0.01–0.04)	0.99	0.98	0.02
		Girls	0.42	0 (0–0.02)	1.00	1.01	0.01	2.55	0.03 (0.02–0.04)	0.98	0.97	0.02
	FR	Boys	2.15	0.03 (0–0.06)	0.99	0.98	0.04	1.96	0.03 (0.02–0.04)	0.98	0.98	0.03
		Girls	1.29	0.01 (0–0.04)	1.00	1.00	0.03	2.85	0.04 (0.03–0.05)	0.98	0.97	0.03
	H	Boys	2.96	0.04 (0.02–0.07)	0.97	0.97	0.05	2.78	0.04 (0.03–0.05)	0.97	0.96	0.04
		Girls	2.02	0.03 (0–0.05)	0.99	0.99	0.04	3.42	0.04 (0.03–0.05)	0.97	0.96	0.03
Food Avoidance Traits	FF	Boys	0.79	0 (0–0.04)	1.00	1.00	0.03	1.76	0.03 (0.01–0.04)	0.99	0.98	0.03
		Girls	0.85	0 (0–0.03)	1.00	1.00	0.02	3.17	0.04 (0.03–0.05)	0.98	0.97	0.02
	EUE	Boys	0.98	0 (0–0.04)	1.00	1.00	0.02	1.76	0.03 (0.01–0.04)	0.99	0.98	0.03
		Girls	3.87	0.05 (0.03–0.07)	0.97	0.97	0.04	3.44	0.04 (0.03–0.05)	0.97	0.96	0.03
	SE	Boys	1.87	0.03 (0–0.05)	0.99	0.99	0.03	2.07	0.03 (0.02–0.04)	0.98	0.98	0.03
		Girls	2.91	0.04 (0.02–0.06)	0.99	0.99	0.04	3.68	0.04 (0.04–0.05)	0.97	0.96	0.03
	SR	Boys	1.87	0.03 (0–0.05)	0.99	0.99	0.03	2.52	0.04 (0.03–0.05)	0.97	0.97	0.03
		Girls	6.57	0.06 (0.04–0.09)	0.97	0.96	0.03	3.51	0.04 (0.03–0.05)	0.97	0.96	0.03

Notes: EF = Enjoyment of Food, EOE = Emotional Overeating, FF = Food Fussiness, EUE = Emotional Undereating, FR = Food Fussiness, H = Hunger, SE = Slowness in Eating, SR = Satiety Responsiveness, LGCM = Latent Growth Curve Modeling, CFI = Comparative Fit Index, TLI = Turker-Lewis Index, RMESA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual

Table 3
Parameter estimates for unconditional latent growth curve models of all appetitive traits by gender.

Unconditional LGCM		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Food Approach Traits		EF		EOE		FR		H	
Intercept	Mean	3.8 ***	4.06 ***	2.14 ***	2.36 ***	2.62 ***	2.94 ***	2.27 ***	2.42 ***
	Variance	0.44 ***	0.35 ***	0.51 ***	0.48 ***	0.44 ***	0.51 ***	0.44 ***	0.45 ***
Slope	Mean	-0.22 ***	-0.13 **	0.16 ***	0.07 **	-0.01	-0.02	0.09 ***	0.06 ***
	Variance	0.15 ***	0.10 ***	0.19 **	0.15 **	0.16 ***	0.13 ***	0.17 ***	0.12 ***
Covariance intercept ↔ slope		-0.11 **	-0.05 *	-0.16 **	-0.08	-0.13 ***	-0.15 ***	-0.13 **	-0.11 ***
Food Avoidance Traits		FF		EUE		SE		SR	
Intercept	Mean	2.47 ***	2.42 ***	2.75 ***	2.92 ***	2.45 ***	2.42 ***	2.45 ***	2.73 ***
	Variance	0.25 ***	0.29 ***	0.56 ***	0.58 ***	0.34 ***	0.42 ***	0.34 ***	0.44 ***
Slope	Mean	0.09 ***	0.16 ***	-0.10 **	-0.05	0.03	0.09 ***	0.03	0.11 ***
	Variance	0.11 ***	0.05 **	0.05	0.19 ***	0.10 **	0.14 ***	0.10 **	0.15 ***
Covariance intercept ↔ slope		-0.07 **	-0.04 *	-0.08	-0.13 **	-0.07 *	-0.11 ***	-0.07 *	-0.10 ***

Note: LGCM = Latent Growth Curve Modeling, EF = Enjoyment of Food, EOE = Emotional Overeating, FF = Food Fussiness, EUE = Emotional Undereating, FR = Food Fussiness, H = Hunger, SE = Slowness in Eating, SR = Satiety Responsiveness * $p < .05$, ** $p < .01$, and *** $p < .001$

nificantly and negatively predicted by the slope of SE for girls, while not significant in boys, suggesting higher growth rate of SE related to lower growth rate of BMI-z scores in girls.

5. Discussion

Generally, our results suggested that the appetitive traits emotional overeating, food fussiness, and hunger significantly increased over time while enjoyment of food decreased over time for both boys and girls. Furthermore, slowness in eating and satiety responsiveness significantly increased over time in girls, while only emotional undereating significantly decreased over time in boys. Moreover, the baseline appetitive traits were significantly and negatively correlated with the change of BMI-z over the 18-month period in emotional undereating and satiety responsiveness in girls, while negative correlations were only found in food fussiness in boys, findings consistent with our hypothesis. However, the result that baseline appetitive traits were significantly and negatively correlated with the change of BMI-z over the 18-month period in hunger was different from our hypothesis. Finally, in line with our hypothesis, the changes in emotional undereating, slowness in eating, and satiety responsiveness were significantly and negatively related to the change in BMI-z in girls, while contrary to our hypothesis, a negative relationship between hunger and BMI was shown in boys.

5.1. Food approach traits

Regarding the first study aim, the increment of hunger among adolescents over the 18-month study period suggests that they tended to feel hungrier during the day as their age increased. Puberty might help explain the increment of hunger among adolescents. Indeed, adolescents consume more energy and their bodies require greater nutritional and caloric intake as they grow [56]. Findings also demonstrated that emotional overeating increased over the 18 months study period which suggests that adolescents might intake more food under emotions as their age increased. Our findings may speak to previous research that emotional eating via inadequate parenting and/or a high degree of de-

Table 4
Estimated mean and 95% confidence intervals of parallel latent growth parameter for eight appetitive traits and BMI by gender when controlling for baseline age.

Appetitive Traits		Parallel LGCM	Boys		Girls	
			Estimate	95% CI	Estimate	95% CI
Food Approach Traits	EF	Intercept (EF) → intercept (BMI)	0.11	(−0.01, 0.23)	0.02	(−0.10, 0.14)
		Intercept (EF) → slope (BMI)	0.002	(−0.07, 0.08)	-0.05	(−0.13, 0.04)
		Slope (EF)→ Slope (BMI)	0.08	(−0.08, 0.23)	0.08	(−0.13, 0.28)
		Intercept (BMI) ↔ slope (BMI)	-0.10 *	(−0.20, −0.002)	-0.07 *	(−0.12, −0.02)
	EOE	Intercept (EOE)→ intercept (BMI)	0.05	(−0.08, 0.18)	0.02	(−0.08, 0.13)
		Intercept (EOE)→ slope (BMI)	-0.03	(−0.11, 0.05)	-0.01	(−0.07, 0.04)
		Slope (EOE)→ Slope (BMI)	-0.12	(−0.34, 0.09)	0.03	(−0.11, 0.18)
		Intercept (BMI) ↔ slope (BMI)	-0.10 *	(−0.20, −0.003)	-0.07 *	(−0.12, −0.01)
	FR	Intercept (FR) → intercept (BMI)	0.08	(−0.06, 0.22)	0.01	(−0.09, 0.10)
		Intercept (FR) → slope (BMI)	-0.06	(−0.16, 0.04)	-0.05	(−0.11, 0.01)
		Slope (FR)→ Slope (BMI)	-0.12	(−0.31, 0.07)	0.08	(−0.09, 0.25)
		Intercept (BMI) ↔ slope (BMI)	-0.10 *	(−0.20, −0.003)	-0.07 *	(−0.12, −0.02)
	H	Intercept (H)→ intercept (BMI)	-0.01	(−0.15, 0.13)	-0.03	(−0.13, 0.08)
		Intercept (H)→ slope (BMI)	-0.06	(−0.16, 0.03)	-0.07 *	(−0.13, −0.01)
		Slope (H)→ Slope (BMI)	-0.20 *	(−0.38, −0.01)	-0.06	(−0.20, 0.09)
		Intercept (BMI) ↔ slope (BMI)	-0.10 *	(−0.20, −0.002)	-0.07 **	(−0.12, −0.02)
Food Avoidance Traits	FF	Intercept (FF) → intercept (BMI)	0.06	(−0.10, 0.23)	0.04	(−0.08, 0.16)
		Intercept (FF) → slope (BMI)	-0.11 *	(−0.20, −0.02)	-0.05	(−0.11, 0.02)
		Slope (FF)→ Slope (BMI)	-0.16	(−0.36, 0.03)	-0.14	(−0.42, 0.14)
		Intercept (BMI) ↔ slope (BMI)	-0.10	(−0.20, 0.002)	-0.07 *	(−0.12, −0.01)
	EUE	Intercept (EUE)→ intercept (BMI)	0.08	(−0.04, 0.20)	0.05	(−0.04, 0.14)
		Intercept (EUE)→ slope (BMI)	-0.07	(−0.16, 0.02)	-0.07 **	(−0.12, −0.03)
		Slope (EUE)→ Slope (BMI)	-0.14	(−0.93, 0.65)	-0.15 *	(−0.27, −0.02)
		Intercept (BMI) ↔ slope (BMI)	-0.10 *	(−0.20, 0.001)	-0.07 *	(−0.12, −0.02)
	SE	Intercept (SE) → intercept (BMI)	-0.36 ***	(−0.50, −0.21)	-0.17 ***	(−0.27, −0.08)
		Intercept (SE) → slope (BMI)	-0.05	(−0.12, 0.03)	-0.04	(−0.09, 0.02)

(*continued on next page*)

Table 4 (*continued*)

Appetitive Traits	Parallel LGCM	Boys		Girls	
		Estimate	95% CI	Estimate	95% CI
	Slope (SE)→ Slope (BMI)	-0.15	(−0.41, 0.10)	-0.20 **	(−0.33, −0.06)
	Intercept (BMI) ↔ slope (BMI)	-0.11 *	(−0.21, −0.01)	-0.07 *	(−0.12, −0.02)
SR	Intercept (SR) → intercept (BMI)	-0.45 ***	(−0.60, −0.31)	-0.22 ***	(−0.33, −0.12)
	Intercept (SR) → slope (BMI)	-0.07	(−0.16, 0.02)	-0.11 ***	(−0.17, −0.06)
	Slope (SR)→ Slope (BMI)	-0.2	(−0.45, 0.04)	-0.29 ***	(−0.44, −0.13)
	Intercept (BMI) ↔ slope (BMI)	-0.11 *	(−0.21, −0.01)	-0.07 **	(−0.12, −0.02)

Notes: LGCM = Latent Growth Curve Modeling, EF = Enjoyment of Food, EOE = Emotional Overeating, FF = Food Fussiness, EUE = Emotional Undereating, FR = Food Fussiness, H = Hunger, SE = Slowness in Eating, SR = Satiety Responsiveness. 95% CI = 95% Confidence Interval, * $p < .05$, ** $p < .01$ and *** $p < .001$

pression/anxiety is associated with poor emotion regulation skills [57, 58]. Moreover, maladaptive emotion regulation strategies may render negative emotions as potent triggers of increased palatable food intake (e.g., increased "comfort" food intake; [59]). Furthermore, increased concerns for their body image and shape among adolescents [60,61] may help further explain the negative impact of emotional overeating on weight status in Chinese adolescents. Taken together, the increase in emotional eating may speak to poor available coping strategies, particularly in the presence of negative emotions, in Chinese adolescents which have implications for weight status later in life.

Finally, hunger related to the growth of BMI among both boys and girls, but with slight differences. The changes of BMI z-scores were negatively influenced by the baseline hunger in girls, suggesting girls who have higher levels of hunger tend to have a lower growth rate of BMI-z scores. In boys, the changes of BMI z-scores were negatively influenced by the changes of hunger, echoing previous findings that hunger was negatively associated with BMI [39]. As discussed before, an unbalanced energy intake might be one explanation for this negative correlation. This gender difference might also be explained by differences in social desirability between boys and girls [62]. More specifically, boys' food intake may reflect their appetite, whereas girls' hunger and subsequent food intake may be influenced by perceptions of having elevated body weight. Moreover, the differences in the timing of pubertal growth spurts in boys and girls might also explain this gender difference [63]. Specifically, girls experience growth spurts sooner in life and during this stage, girls may be more likely to engage in dieting for thinness than boys [64]. Considering that dieting behaviors were not assessed in the present study, future studies are needed to assess the potential effects of dieting on the present findings. In addition, even though most studies using the AEBQ kept the Hunger subscale, the suitability of the Hunger subscale remains controversial, as there is evidence showing that the exclusion of the subscale improved the model fit of the AEBQ in adolescents [47]. Thus, further study is needed to better understand the potential mechanisms of how hunger is related to BMI in adolescent boys and girls.

5.2. Food avoidance traits

We observed gender differences among food avoidance appetitive traits over the 18-months study period. More specifically, slowness in eating and satiety responsiveness increased over time in girls while emotional undereating decreased over time in boys. These findings build on Ashcroft and colleagues [65] which suggested that appetitive traits of emotional undereating significantly decreased over time in a sample of children from England and Wales. Other research has identified a similar gender effect with the appetitive traits of satiety responsiveness and slowness in eating in a sample of London girls [47]. Furthermore, such findings may reflect restrained eating and higher social desirability of dieting among adolescent girls [41].

We also found that the baseline level and changes of emotional undereating were negatively associated with the BMI z-scores only in girls, suggesting girls who have a higher level of emotional undereating tend to have decreased growth rates of BMI z-score. Interestingly, previous research has found that children's emotion regulation was correlated with appetitive traits [59], and food avoidant eating patterns were shown to be more common in children with higher emotional temperaments [66]. Furthermore, such emotional temperaments may correspond to decreased BMI. Gender differences have been identified by family functioning and family resources in the Asian group [67]. More specifically, since women were perceived to have better affective (i.e., emotional) involvement while males were perceived to have better physical and mental well-being, it may be the case that perceived family functioning among children may be an important factor in explaining gender differences in the effect of emotional undereating on BMI in girls. Further research is needed to explore these effects by gender within the Chinese context.

Regarding the second study aim, we also found that the changes of BMI z-scores were negatively influenced by the baseline level and changes of satiety responsiveness in girls. Previous research suggested that the appetitive trait satiety responsiveness may predict lower energy intake which, in turn, may be related to having a lower BMI z-score in toddlerhood [68]. An investigation among children with obesity from Brazil further revealed that a low level of satiety responsiveness may be implicated in a decreased ability to regulate their food intake [69]. This irregular food intake might be influenced by gender differences given women generally showed greater dieting behavior than men [70].

Building on above, we found that the changes of slowness in eating in girls were negatively associated with the change of BMI z-scores in girls, suggesting a potential gender difference in this appetitive trait in relation to weight status. Slowness in eating refers to eating food at slower rates. Furthermore, high slowness in eating in children may indicate less interest in food [71], which explains the decreased change of BMI z-score. This result echoes previous findings that girls with severe obesity have lower slowness in eating than those with obesity [72]. Furthermore, in comparison to boys, girls exhibited a greater tendency for food avoidance behavior which may provide further information on the observed gender effect between slowness in eating and weight status [73].

Furthermore, we found that the changes of BMI z-scores in boys were negatively influenced by the baseline level of food fussiness. The same correlation was found in previous research [24,74], which suggested that the adolescents who were perceived to be pickier and less willing to try new foods tended to also have a lower weight status. A possible reason might be that fussiness limits the quantity of overall eating, and thus the amount of calories consumed, which may correspond to the observed lower weight status [75]. As such, it is necessary for future research to better understand how the above factors may help explain the observed gender difference in food fussiness and weight status among Chinese adolescents.

Indeed, our findings suggest that food fussiness may be a stable phenotypic behavior that may predict future changes in BMI z-scores in boys, but not girls, which is in line with previous studies that food neophilia was found to distinguish men and women [76]. However, the gender differences in food neophobia are not yet agreed upon. Some research has reported that food neophobia has an even impact on both males and females [77–80], while Tuorila and colleagues [81] found that men were more neophobic than women in Nordic countries. Future study is needed to clarify these discrepancies.

5.3. Prevention and treatment implications

The findings of the present study have implications for the prevention and intervention of childhood overweight and obesity in the Chinese context. Specifically, in line with the conception of intervention at appetitive traits [4,15,82], certain appetitive traits (e.g., slowness in eating and satiety responsiveness) can be targeted for obesity prevention in Chinese adolescents. As such, researchers and clinicians may identify adolescents who are at high risk of overweight/obesity by monitoring certain appetitive traits such as emotional undereating, hunger, slowness in eating, satiety responsiveness, and food fussiness given their associations with weight status over time. Moreover, as clear gender differences were also revealed, the design of future interventions focusing on appetitive traits should consider gender differences. Given are no available intervention studies about appetitive traits and weight status in China, the effectiveness of these interventions on childhood obesity prevention should be explored in future research.

5.4. Strengths, limitations, and future directions

The major strengths of the present study were exploring the relationships between appetitive traits and BMI in a large sample of Chinese adolescents, as well as using a longitudinal design. Despite the strengths, in interpreting the results of this study, several limitations and future research directions need to also be considered. First, the present study used convenience sampling, which may lack representativeness and potentially introduce some bias in the sample. Moreover, only gender and age were controlled in this study which may have limited the observed temporal relationships between appetitive traits and BMI. Specifically, due to the design of the project, we only collected other characteristics (e.g., parental marital status, family income, father's education, and mother's education) from the participants who provided valid data in the first wave of data collection, which leads to 18.77% missing data for these characteristics for the total sample. Thus, we did not control the other characteristics which should be included and controlled in future studies to further confirm the findings of the present study. In addition, the results of correlation analyses showed that there were no significant correlations between these characteristics and BMI-z at Wave 1. Thus, not controlling the other characteristics is not likely to affect the findings of the present study. Furthermore, both appetitive traits and BMI were based on participants' self-reported information which may decrease the validity of the findings. Therefore, future research should use direct measurements of appetitive traits and BMI to validate the findings of the present study. Moreover, it should be noted that our study was conducted in a timeframe of 18 months, which is a relatively short period for a longitudinal study. Thus, even though we found significant parameters in the estimated LGCMs, it remains unclear whether adolescents' appetitive traits or weight changed enough in this short period or whether the changes were related to intraindividual variability in appetitive traits and/or weight, especially considering that the effects observed in the present study can confound with other factors such as age, gender, and the onset of puberty. Thus, future studies with longer timeframes are warranted to confirm the present findings.

6. Conclusion

The present study suggests that appetitive traits of Chinese boys and girls can change over time with different patterns, and the change of certain appetitive traits may be related to adolescents' weight status. Future interventions that are sensitive to probing gender differences are needed to examine whether targeting certain appetitive traits (e.g., emotional undereating, hunger, food fussiness, slowness in eating, and satiety responsiveness) are effective in the weight management of Chinese adolescents.

Ethical Statement

Ethical approval was obtained from the research ethics office of Hengyang Normal University. All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Moreover, the work has not been published previously or under consideration for publication elsewhere. All authors have reviewed and approved this submission. All the authors declare that they have no conflict of interest.

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Ethics approval

All procedures performed in this study involving human participants were in accordance with the ethical standards of Hengyang Normal University and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to participate

The ethical approval was obtained from the Research Ethics Office of Hengyang Normal University. All participants and their custodians provided consent to participate.

Consent for publication

Not applicable.

CRediT authorship contribution statement

Y.C. conducted the statistical analyses and drafted the manuscript. W.R.B helped draft the manuscript. G.C. helped with the study design, results interpretation, and helped draft the manuscript; G.L. helped with statistical analyses and helped draft the manuscript. T.L. and J.H. conceptualized the study, led the study design and results interpretation, and helped draft the manuscript. All authors approved the final version of the manuscript for submission.

Conflicts of interest

No conflict of interest declared.

Data Availability

Data is available from the corresponding author upon reasonable request.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.orcp.2022.12.002.

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