Developmental Trajectories of Adolescent Overweight/Obesity in China: SES Correlates and Health Consequences

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Abstract

Background: During recent decades, China has experienced rapid growth in economy and also in prevalence of childhood obesity. Given the great importance of adolescence overweight/obesity for future health, and given the relative lack of longitudinal studies on adolescent obesity in developing countries, particularly in China, in current study, we aimed to explore the potential growth trajectories of overweight/obesity among Chinese adolescents and to further examine socioeconomic status predictors and health consequences of these growth trajectories.

Methods: The data were from four waves of panel data from the China Family Panel Studies (CFPS 2010, 2012, 2014, and 2016). For the current study, children aged 10 to 12 from the baseline 2010 sample were selected (N = 1685), among whom 1388 were re-interviewed in 2012, 1172 in 2014, and 941 in 2016. We retained a final sample of 800 who had at least three waves of BMI data (i.e. final N = 800). Generalized growth mixture modeling (GGMM) was used as the major analytical strategy.

Results: We found that three types of overweight/obesity developmental trajectories may exist for those Chinese adolescents including a stably normal class, a decreased risk class, and a chronically overweight/obese class. Additionally, we found that higher family income was associated with a lower probability of getting into the chronically overweight/obese class for urban adolescents, but with a higher probability of getting into the same class for rural adolescents. Finally, we found that the adolescents in the chronically overweight/obese group reported significantly lower levels of self-rated health.

Conclusions: There were heterogeneous growth trajectories of Chinese adolescent overweight/obesity. Sustained overweight/obesity during adolescence was predicted by lower family income in urban China but by higher family income in rural China. More targeted and regionalized interventions for children's overweight/obesity in China should be considered. **Keywords:** China; adolescent overweight/obesity trajectories; SES; self-rated health; CFPS

Background

With the process of worldwide nutrition transition, overweight and obesity is rapidly spreading among developing countries [1-2]. As the largest developing nation, China has seen a huge surge in overweight and obese population in the past several decades, due to its rapid economic growth and the resultant rising living standard and changing lifestyles [3-4]. In the past few decades, overweight and obesity among Chinese children have increased at an increasingly higher speed [5]. For instance, It has been found that the prevalence rate of overweight/obesity for children aged 6-17 has more than doubled from the years 1991 to 2011, from 11.7% to 25.2% [6]. Given the widely acknowledged long-term

adverse impact of childhood obesity on adult health, including continuing adulthood obesity, elevated risks of cardiovascular and metabolic diseases and all-cause mortality [7-9], it is of great necessity to scrutinize the developmental characteristics and unequal patterns of overweight/obesity among Chinese children and adolescents to find ways to slow down its spreading speed and lessen future disease burdens.

Regarding SES correlates of childhood overweight/obesity, research using single or repeated cross-sectional data has found that the correlation between socioeconomic status and overweight/obesity varies between developed and developing countries [10]. For children in developed countries, studies have found a predominantly inverse relationship between SES and obesity [11-12]. However, based on relatively limited evidence from developing countries, SES was found to be positively correlated with rates of obesity among both adults and children [13-14]. For Chinese children, researchers have similarly found that the impact of family SES on childhood overweight/obesity is positive and has widened over time [15-16].

More recently in research using panel data and person-centered approach, it has been argued that there are various developmental trajectories of childhood overweight/obesity [17-18]. The majority of these studies reported that the developmental trajectories of childhood obesity were indeed heterogeneous, and there were usually three to four distinct “latent” classes necessary for depicting different growth patterns. This research has found that higher SES background decreases the likelihood of persistent or elevated risk of overweight and obesity over time [19-21]. Meanwhile, this body of longitudinal research has also found that the risky developmental trajectories of childhood obesity is associated with serious synchronous morbidity, such as asthma and lung functioning [22], adolescent metabolic health outcomes (e.g., waist circumference, insulin resistance, and total cholesterol) [23], non-alcohol fatty liver disease [24], and dental health [25].

However, almost all these studies on SES correlates and health consequences of childhood obesity trajectories have focused on developed countries. In light of the persisting rural-urban disparities and rising socioeconomic inequalities [26], it remains poorly

understood how the developmental characteristics of overweight/obesity among Chinese children vary across different socioeconomic strata and between urban and rural areas. Therefore, we draw on longitudinal data from four waves of the China Family Panel Study (CFPS), a large-scale ongoing nationally representative survey, to examine the developmental trajectories of Chinese adolescent overweight/obesity, and the potential SES determinants and health consequences of those growth trajectories. Taking into account the great and persisting rural-urban economic, socio-cultural and well-being disparities in China [27], we made explicit comparisons between urban and rural adolescents in the analysis.

Methods

Data

The data for this study came from four waves of the China Family Panel Studies (CFPS). The CFPS baseline survey was conducted in 2010, and it selected samples from 25 provinces/municipalities/autonomous regions using a PPS sampling method with implicit stratification, representing 95% of the Chinese population (CFPS User's manual, 3rd edition). The baseline sample was followed up with, biannually in 2012, 2014, and 2016. The 2010 baseline survey interviewed 8990 children aged 0 to 15[1].

For the current analysis, children aged 10 to 12 from the baseline 2010 sample were selected ($N = 1685$). At the end of the study coverage, they were 16-18 years old in 2016. This age range corresponds to the biologically critical stage of the adolescent spurt, which occurs between the ages of 10 and 18. Among the original sample, 1388 were re-interviewed in 2012, 1172 in 2014, and 941 in 2016. For the purpose of this study, we retained a final sample of 800 adolescents who had at least three waves of BMI data (i.e. final $N = 800$). Combined with the four waves of available data, we have 3200 observations in total.

Measures

Repeated measures of the observed dependent variables: A binary measure of being overweight or not was used for each of the four waves in 2010, 2012, 2014, and 2016 as our dependent variable. First, adolescent raw BMI scores were computed based on self-reported weights and heights. Second, age- and sex-specific BMI z-scores were calculated according to WHO child growth standards and WHO reference 2007, which were then transformed to age- and sex-specific percentiles for BMI [28]. Finally, according to the CDC cut-points[2], we used the 85th percentile as a cutoff to construct the binary variable of being overweight and obese. Thus, the dependent variable of being overweight or not, included both overweight and obese children in the study.

Predictors at the baseline: We computed all the covariates based on the 2010 baseline data and treated them as time-constant in the modeling specification. First, family SES indicators are our key predictors for class membership of adolescent overweight/obesity. Parental education, family income and parental occupation were used for measuring family SES. Parental education (the higher one between father's and mother's education) was classified into three categories including six years or less (reference), nine years of education, and 12 years or more of education. Family income was divided into low (below 25%) (reference), lower medium (25% to 50%), upper medium (50% to 75%), and high (above 75%) income. Similarly, we categorized parental occupations into four general types including agricultural related jobs (reference), administrative/technical jobs, service/factorial jobs, and other jobs which were missing or unable to be classified.

Subsequent health outcomes: Overall physical health was measured by adolescent self-rated general health in 2016 on a 5-point scale (1–5) with higher scores indicating better self-rated health.

Other covariates that were controlled for include: gender, race, *hukou*, place of residence (urban vs. rural), family structure (whether living in a two-parents household), average BMI for adult family members, region (East, Middle, West, and Northeast), physical exercise, and breastfeeding type. Furthermore, self-rated health at baseline was

also included as variables that were controlled for in predicting subsequent health outcomes. Detailed descriptive statistics of these variables can be found in Table 1.

Table 1 Summary Statistics for Key Variables by Place of Residence

	Urban Area	Rural Area	Full Sample
	(N =303)	(N = 497)	(N = 800)
Variables	Mean (S.E.)	Mean (S.E.)	Mean (S.E.)
	/ (%)	/ (%)	/ (%)
Family Income Categories			
Low (below 25 %) (reference)	16.5%	29.18%	24.36%
Lower medium (25% to 50 %)	24.09%	37.02%	32.13%
Upper medium (50 % to 75 %)	30.03%	23.34%	25.88%
High (above 75 %)	29.37%	10.46%	17.63%
Parental Education			
6 years or less (reference)	15.84%	46.68%	35.00%
9 years	42.90%	39.24%	40.63%
12 years or more	41.25%	14.08%	24.38%
Parental Occupation			
Agricultural related job (reference)	14.85%	53.12%	38.63%
Administrative/technical job	17.49%	5.03%	9.75%
Service / factorial job	52.81%	31.79%	39.75%
Other job	14.85%	10.06%	11.88%
Gender (male = 1)	53.47%	50.30%	51.50%
Race (<i>Han</i> = 1)	91.09%	87.73%	89.00%
<i>Hukou</i> (Agricultural = 1)	49.5%	95.77%	78.25%
Region			
East (reference)	39.93%	19.11%	27%
Middle	26.07%	27.36%	26.88%
West	19.14%	44.47%	34.88%
Northeast	14.85%	9.05%	11.25%
Two-Parent Household (Yes = 1)	90.43%	93.16%	92.13%
Physical Exercise			
Never (reference)	21.12%	23.34%	22.50%

Several times a month	14.19%	11.67%	12.63%
Often	64.69%	64.99%	64.88%
Breast Feeding Type			
Never (reference)	5.61%	3.62%	4.38%
1 to 6 months	17.16%	6.44%	10.50%
More than 6 months	77.23%	89.94%	85.13%
Average BMI of Adult Family Members	22.61 (2.75)	21.10 (3.73)	21.67 (3.47)
Depression in 2010	1.41 (0.58)	1.46 (0.65)	1.44 (0.63)
Self-Rated Health in 2010	4.69 (0.63)	4.75 (0.54)	4.72 (0.57)
Depression in 2016	30.26 (5.95)	30.55 (5.82)	30.43 (5.87)
Self-Rated Health in 2016	3.76 (0.99)	3.79 (0.93)	3.78 (0.96)

Modelling strategy

Generalized growth mixture modeling (GGMM) [30-31] was used as the major analytical framework in the study. As the first step, latent class growth analysis (LCGA) was used to identify heterogeneity in developmental trajectories of being overweight/obesity among Chinese adolescents. Then a three-step approach [32-33] and BCH methods [34] were adopted to further identify the SES profiles of each subclass and to predict the distal health outcome of class membership. The general model diagram for our analysis is illustrated in Figure 1.

It should be noted that sample attrition is a common issue for longitudinal studies like this. Preliminary examinations showed that attrition was not related with baseline BMI along with many other covariates examined in the study, and this gives us some ground that the assumption of missing at random, which is required by the estimation technique applied in this analysis (i.e. Full Information Maximum Likelihood, FIML), may be a reasonable one to make.

[Insert Figure 1 here: GGMM Model diagram illustration]

[1] This data set is accessible to any individual who want to use it for a secondary data analysis. CFPS data was collected by a research team from Peking University in China and it has gained required ethic approval for data collection from human subjects. All the related information can be found at their website:

<http://www.isss.pku.edu.cn/cfps/index.htm>

[2] Although not unanimously agreed, some research suggested that the three major criteria of weight classification (i.e. IOTF, WHO, and CDC) agreed substantially and can be considered comparable in research [29].

Results

Descriptive Profiles of Adolescent Overweight/Obesity in China

The overall trend of overweight prevalence for Chinese adolescents declined from 23% to 8% over time for the studied full sample. However, there exists substantial differences both between gender and place of residence in terms of the prevalence of childhood overweight/obesity. Fig. 2 displays the time trend of the prevalence of overweight by gender and by place of residence (urban/rural) respectively. The prevalence of overweight for boys (from 28% to 10%) is consistently higher than that found for girls (from 18% to 5%) in an almost parallel way over time. The prevalence of overweight for urban children aged 10-12 (22%) is similar to that for rural children (23%) in 2010. Nonetheless, the prevalence of overweight and obesity for rural adolescents declines steadily faster than that for urban adolescents during the follow-up period. At the age of 16 to 18, the prevalence of overweight for urban adolescents is 10% while it is 7% for their rural counterparts.

[Insert Figure 2 here: Prevalence of adolescent overweight by gender and place of residence across time]

We first estimated latent class growth analysis (LCGA) models that allowed for different numbers of latent classes of overweight trajectories. The corresponding model fit indices are shown in Table 2. Among all the potential models, the three-class solution has the lowest ABIC value and the most reasonable size and shape for each class. The retrieved three classes also make theoretical and substantive sense. Therefore, we will focus on the three-class model for the subsequent analysis[1].

Table 2 Model fit indices for difference number of latent classes

# of classes	1	2	3	4
# of parameters	2	5	8	11
Log likelihood	-1201.880	-1010.641	-994.395	-994.015
BIC	2417.240	2054.979	2042.705	2062.162
AIC	2407.761	2031.283	2004.790	2010.029
ABIC	2410.888	2039.101	2017.300	2027.230
Entropy	—	0.919	0.636	0.652
LMR	—	p = 0.0000	p = 0.0012	p = 0.0022
Class size	100%	91.3% / 8.7%	57.6% / 36.4% / 6.1%	50.5% / 1.2% / 6.3% / 42%

As is shown in Fig. 3, we defined Class 1 (57.6%) as a stable low-risk or normal group, Class 2 (36.4%) as a decreased-risk group, and Class 3 (6.1%) as a sustained high-risk group. For Class 1, the probability of getting overweight is consistently close to zero over time. Class 2 initially has a medium risk of being overweight, which however goes down over time and eventually converges with the first class. In comparison, Class 3 had a consistently high probability (over 90%) of being overweight over the study period.

[Insert Fig. 3 here: Heterogeneous developmental trajectories of overweight and obesity for the full sample]

We further estimated the three-class LCGA model separately by gender and by urban/rural division (Fig. 4). Among the sampled girls, only 2.6% were classified into the stable high-risk group (Class 3), while for the boys, it is 9.4%. There are 8.4% of urban adolescents who were classified into the stable high-risk group (Class 3), while it is only 4.8% for rural adolescents[2]. This verifies the gender and rural-urban differences in adolescent overweight/obesity that we observed in the above section.

[Insert Figure 4 here: BMI developmental trajectories by place of residence and gender]

SES predictors of class membership

We used the 3-step approach developed by Vermunt (2010) to estimate the association between the predictor variables and the latent class variable. R3STEP option in Mplus was used to specify the auxiliary variables in the model as predictors rather than distal outcomes of the latent class variable. Along with the regular latent class growth model, each observation was assigned to a most likely class variable N by taking measurement error or classification uncertainty rate into account [3]. In the last step, a multinomial logistic regression model was estimated, in which SES indicators and other controlling covariates predicted the most likely class variable N.

As is mentioned above, the substantial economic and socio-cultural disparities between urban and rural China may lead to fundamental differences in lifestyles, nutrition status, and SES-obesity patterns between urban and rural children. Thus, it was critical to analyze the SES-BMI trajectories separately for both urban and rural adolescents. In fact, in the analysis with the full sample, neither family income nor parental education was found to be

significantly associated with the latent class membership of BMI trajectories. However, separate analyses for the urban and rural sub-samples revealed more nuances about the potential underlying patterns (Table 3).

Specifically, for the urban sample, since less than one percent of the sampled girls was classified into the sustained high-risk group, we estimated the association between family SES and class memberships only for the urban boys, among whom 14% was classified into the sustained high-risk group. The results show that higher level of family income in urban area consistently predicts a lower probability of getting into stable high-risk group (ORs = 0.23, 0.14, and 0.23 for the three levels of family income). However, the opposite pattern was found for rural adolescents, in which higher level of family income seemed to increase the probability of stably staying in the high-risk group (ORs = 5.85, 4.34, and 2.66), with only the first income level being statistically significant. In addition, compared to agricultural work, rural adolescents whose parents engage in administrative/technical jobs (OR = 24.21) were also more likely to get into the high-risk class. Further complementary analyses for rural girls and rural boys show similar patterns as reported above.

Table 3 Multinomial Logit Models of Stable High-Risk BMI Class and Normal Class for the Urban and Rural Samples ^a

	Urban (Male)		Rural	
	High vs. Normal		High vs. Normal	
<i>SES Determinants</i>	O. R.	S. E.	O. R.	S. E.
Family Income				
[Low income (below 25 %) as reference]				
Lower medium (25% to 50 %)	0.23 ⁺	0.88	5.85 [*]	0.92
Upper medium (50 % to 75 %)	0.14 [*]	0.98	4.34	1.09
High (above 75 %)	0.23 ⁺	0.95	2.66	1.13
Parental Education				
[6 years or less of education as reference]				
9 years	1.45	1.24	0.54	0.75
12 or more years	0.99	1.45	0.54	0.92
Parental Occupation				
[Agricultural related job as reference]				
Administrative/technical job	3.89	1.45	24.21 ^{**}	1.09
Non-agricultural service / factorial job	1.59	1.28	0.56	0.85
Other job	2.02	1.16	5.77	1.60

Note: a. The dependent variable was a three-category nominal variable, but only the comparison between stable high-risk class and normal class was reported in Table 2; b. Results for the control variables in the model was omitted in Table 2; c. ⁺p 0.1; ^{*}p 0.05; ^{**}p 0.01; ^{***}p 0.001.

Health consequences of Adolescent Overweight/Obesity

We first compared the mean differences among the three classes of overweight/obesity trajectories in adolescents' self-rated health without controlling any covariates. This was

done by using the automatic BCH procedure in Mplus. The results show that the sustained high-risk class (class 3) shows significantly lower self-rated health than the decreased risk class. We then further checked these results by including more controls in the model. That is, we predicted the distal outcomes (self-rated health) from the three latent classes while controlling for the effects of other possible confounding variables. This procedure was conducted by using the manual BCH method which estimated a multiple group model with each observation adjusted by a group-specific weight. The class-specific intercepts of self-rated health in 2016 are 3.72 (Class 1), 3.81 (Class 2), and 3.46 (Class 3), after controlling for gender, parental education, family income and baseline self-rated health in 2010. The Wald's Chi-square test shows that the sustained high-risk group (Class 3) had significantly lower self-rated health than the normal group (Class 1) and the decreased-risk group (Class 2).

[1] We also replicated the 3-class solution by an alternative model specification allowing for growth factor variation within each class.

[2] In the complementary analysis, we found that almost all of the 2.6% of the sampled girls who were classified into Class 3 are from rural areas, whereas a much higher proportion of urban boys were classified into Class 3 than rural boys (14.1% vs. 6.7%).

[3] N is treated as an imperfect indicator of the latent class variable C with measurement error defined by the logits for the classification probabilities for most likely class membership [33].

Discussion

This study is among the first that specifically focuses on the developmental trajectories of adolescent overweight/obesity in China. Based on a nationally representative longitudinal survey, we identified three heterogeneous classes of developmental trajectories for adolescent BMI, and examine their associated SES precursors and subsequent health outcomes. Three major findings from our study are worthy of further attention and discussion.

First, the three classes of BMI developmental trajectories identified in our study are not identical to those typically found in Western societies. In previous studies on Western children, the proportion of consistently normal is higher and a late onset class is usually identified [17-18]. Given the data-driven nature of latent class analysis, further research should examine these disparities with different and larger representative data of Chinese adolescents.

Second, regarding the association between family SES indicators and adolescent BMI trajectory types, the most critical finding in our study is that the effect of family income on adolescent overweight/obesity is in the opposite direction for urban and rural China. That is, higher family income in urban areas seems to protect urban boys from the risk of sustained overweight/obesity, while it increases the same risk for rural adolescents. Furthermore, we found that for rural adolescents, the effect of parental occupation is consistent with that of family income. The social stratification research on contemporary China suggests that rural residents who live purely on agricultural income has become the lowest class in current rural society, while those who occupy village administrative positions (the so-called “rural cadres”) has become the highest class [35]. Taken together, our findings suggest that urban China is ahead of rural China in terms of nutrition transition. We speculate that urban China on average may have entered into the “behavioral change” stage while the rural areas on average are still experiencing the “degenerative diseases” stage[1] according to the nutrition transition theory [1]. But this speculation should be interpreted with caution and further research.

Third, we found that adolescents who are chronically overweight/obese reported significantly lower self-rated health. In other words, negative physical health consequence may have started emerging for these young people. However, given the limitation of data, we are unable to examine more specific health consequences of childhood overweight/obesity[2]. Future research should investigate the association between BMI trajectories with specific types of health problems, which may be highly likely to occur during adolescence and early adulthood, such as asthma [22].

Although our research findings are quite enlightening, there are limitations that should be acknowledged. First, our sample was selected from a nationally representative data set but the sample size of adolescents was relatively small, which may have hampered our capability of detecting more complete and accurate patterns of adolescent overweight/obesity in China. Second, our BMI data were based on self-reported weights and heights[3], which might lead to some systematic bias in the estimation of overweight prevalence. The accuracy of self-reported height and weight is greatly debated in the literature [36-38]. Third, research has shown that rural adolescents in China are experiencing double burdens of both under-nutrition and over-nutrition [39]. In this study, we focused only on the issue of overweight/obesity and its correlates, and thus do not distinguish being normal from being underweight. However, child underweight in China may be worthy of special attention.

[1] The “degenerative disease” pattern is characterized with a diet high in total fat, sugar, and cholesterol etc., accompanied by a sedentary life style and thus resulting in increased prevalence of obesity and related degenerative disease. The “behavioral change” pattern is characterized with a change toward a healthier life style such as less fat and processing food and more exercise to delay generative disease and promote health (Popkin, 1993).

[2] In our sample, only 27 children reported some kind of chronic disease in 2016. Seven of them were upper respiratory tract infection and eight were gastroenteritis.

[3] From wave 1 to wave 3, parents reported their children’s weights and heights, and in wave 4 the adolescents reported their own anthropometric data.

Conclusions

This study provides some evidence on the potential overweight/obesity developmental trajectories as well as SES determinants and subsequent health consequence of those growth trajectories among Chinese adolescents, which has been largely absent in the current literature. Despite the limitations discussed above, this study still sheds light on the complicated patterns of SES-BMI growth trajectories among Chinese adolescents during the great social transformation era in China. The overweight prevalence of urban

adolescents is much higher than rural children, which implies that more economically developed areas need more intense interventions on this public health threat. Moreover, in developing effective interventions, different risk factors should be considered for urban and rural areas in that the SES correlates of overweight/obesity seem to be quite opposite for urban and rural adolescents. While poverty in urban areas is a risk factor for adolescent overweight, being rich in rural areas may be equally dangerous for childhood overweight. Therefore, we argue that the economic division between urban and rural China is a fundamental force in shaping different stages of nutrition transition and leads to different associations between SES and children's BMI trajectories. Contemporary China is not experiencing one single nutrition transitional stage but rather a mixture of nutrition transition. In this regard, it is crucial to identify context-specific public health threats and develop strategic counteracts accordingly.

Declarations

Abbreviations

CFPS: China Family Panel Studies; CDC: Centers for Disease Control and Prevention; GGMM: Generalized growth mixture modeling; IOTF: International Obesity Task Force; SES: Socioeconomic Status; WHO: the World Health Organization;

Acknowledgements

Not applicable.

Authors' contributions

YL was responsible for the overall study design, part of literature search and summary, data analysis and manuscript development. YQQ was responsible for part of literature search and writing, some complementary data analysis and some final revisions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

CFPS data is publicly available on its website: <http://www.issp.pku.edu.cn/cfps/>. The sub-data set used in the current study is available from the corresponding author on request.

Ethics approval and consent to participate

Not required owing to the design of the research (a secondary analysis of de-identified public data)

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no conflict of interest

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Figures

Figure 1. GGMM Model diagram illustration

Figure 1

GGMM Model diagram illustration

Figure 2. Prevalence of adolescent overweight by gender and place of residence
across time

Figure 2

prevalence of adolescent overweight by gender and place of residence across time

Figure 3. Heterogeneous developmental trajectories of overweight and obesity for the full sample

Figure 3

Heterogeneous developmental trajectories of overweight and obesity for the full sample

Figure 4. Heterogeneous developmental trajectories of overweight and obesity by place of residence and by gender

Figure 4

BMI developmental trajectories by place of residence and gender