Sex, Socioeconomic and Regional Disparities in BMI Trajectories across Childhood and Their Implications on Underweight and Overweight in Reform-era China

ABSTRACT

Based on a longitudinal dataset of the China Health and Nutrition Survey (CHNS), we employ growth curve models to examine sex, socioeconomic and regional disparities in BMI trajectories across childhood and their implications on underweight and overweight in reform-era China. Sex, family income, rural-urban residency and geographical locations (but not for parental education) are found to be significantly associated with differential age trajectories in childhood underweight and overweight from age 6 and age 16. For a specific socio-demographic group, children who have lower prevalence of underweight in the transition from childhood to adolescence (such as boys, children from high-income families, children living in urban areas, northern China or non-western regions) also exhibit higher prevalence of overweight than their counterparts do. Moreover, the age interval during which children are more vulnerable to the increase in underweight is different from that of overweight (age 12 is the tipping point).

Key words: Underweight, Overweight, Age Trajectories, Body Mass Index, China

INTRODUCTION

Childhood overweight and underweight are two epidemiological problems with essential consequences not only because they can extend to adulthood but because they are associated with the early onset of a series of diseases and excess deaths (Atlantis & Baker, 2008; Bongaarts, 2006; Dietz, 1998; Flegal et al., 2005, 2007; Olshansky et al., 2005; Barry Popkin, 2009). While the global rise of childhood obesity and its association with demographic, socio-economic and spatial factors are drawing increasing attention from epidemiologists and social scientists, it has been argued that households at both developed and developing countries can face dual burden of nutritional problems (the coexistence of both underweight and overweight persons) during the nutrition transition (Anderson & Butcher, 2006; Doak et al., 2004; Gordon-Larsen et al., 2006; Scharoun-Lee et al., 2009; Y. Wang, 2001; Y. Wang et al., 2002; Zhang & Wang, 2004). With regard to research on the socioeconomic gradients in both underweight and overweight, studies on China can shed light on the progress of the two global epidemics not only because the nutrition transition in China is believed to be intertwined with the growth of its market economy, but because a substantial increase in the prevalence of childhood overweight has been documented in this populous country once characterized by the scarcity of food and economic resources not a long time ago (Cui et al., 2010; Johnson et al., 2006; Luo & Hu, 2002; BM Popkin, 1998).

Since China fully embraced a market economy in the early 1990s, this country has grown mightily in terms of production, foreign exchange reserves, savings and exportation. While it is widely agreed that the influence of this gigantic reform has spread to every corner of social and economic life in China, there is considerable evidence that the development of childhood overweight and underweight is also associated with socio-economic determinants in reform-era China. Based on longitudinal data from the China Health and Nutrition Survey (CHNS), a six-year follow-up study (1991-1997) showed that children from high-income families tended to move up to a higher BMI (body mass index) quartile group six years later, whereas children from low-income families tended to move down to a lower BMI quartile group (Y. Wang et al., 2000). Based on the same dataset, a longitudinal analysis of BMI, which documented a rapid increase in the prevalence of childhood obesity (from 1.5% in 1989 to 12.6% in 1997) in urban China, revealed that China's rural-urban divide was significantly associated with the growth of childhood BMI (944 children aged 2-6 in 1989). Net of other effects, boys had higher BMI than girls (Luo & Hu, 2002). With regard to other socioeconomic measures, a cross-sectional study comprising 824 students aged 12 to 14 years demonstrated that parental education has significantly positive effect for boys' BMI (Shi et al., 2005). A recent study based on children surveyed from 1991 to 2006 also reported that boys and children from higher income families tended to have higher prevalence of overweight and obesity (Cui et al., 2010). Although inadequate research has been conducted on the socioeconomic gradients of childhood underweight in China, a cross-sectional study demonstrated that household income, household head's education, provincial differentials and urban residence are significantly associated with inequality of childhood malnutrition in the year 2000 and the authors highlighted the contribution of spatial factors on childhood malnutrition and its consequences, such as underweight (Z. Chen et al., 2007). Based on the 1993 China Health and Nutrition Survey, it was found that the majority of underweight households (78.6%) were concentrated on southern China (Doak et al., 2002). Furthermore, it has been argued that both increase in the prevalence of childhood overweight and decrease in the prevalence of childhood underweight taking place in China from 1991 to 1997 can be attributed to the availability of economic resources during the economic transformation (Y. Wang et al., 2002).

Whereas existing research have suggested sex, socioeconomic and regional disparities in the epidemics of childhood overweight and underweight in China, scholars remains unclear whether demographical, socio-economic and spatial characteristics at the individual level are associated with children' BMI trajectories and their likelihood of being underweight or overweight across childhood in reform-era China. Based on a longitudinal dataset of the China Health and Nutrition Survey (CHNS), we employ growth curve models to examine sex, socioeconomic and regional disparities in BMI trajectories across childhood and their implications on underweight and overweight in reform-era China.

METHODS

Sample

This research is based on data from the China Health and Nutrition Survey (CHNS), a collaborative project conducted by the Carolina Population Center at the University of North Carolina at Chapel Hill, the National Institute of Nutrition and Food Safety in China and the Chinese Center for Disease Control and Prevention. Although this survey is not nationally representative, this ongoing open-cohort survey that provides nationally representative information on the nutrition and health status of the Chinese population covers nine provinces (*Guangxi*, *Guizhou*, *Heilongjiang*, *Henan*, *Hubei*, *Hunan*, *Jiangsu*, *Liaoning*, and *Shandong*) in China which varies substantially in terms of geography, economy, social development, dietary patterns and health indicators. Subjects within each province were selected using a multi-stage, stratified clustering sampling scheme. As the CHNS has been proposed to study how social changes and economic transformation in China influence the health status and nutritional patterns of its population, a series of demographic, socio-economic and demographic indicators were included. The study was initiated in 1989 and continues to the present. To examine sex, socioeconomic and regional disparities in BMI trajectories in reform-era China, the sample includes 1,694 children age 2-11 years (N = 1,694) who were interviewed in 1993.[1] Follow-up interviews were conducted in 1997 when they were age 6-15 (N = 1,222), in 2000 at ages 9-18 (N = 1,075), in 2004 at ages 13-22 (N = 471) and in 2006 at

[1] Because Heilongjiang Province replaced Liaoning Province in the 1997 wave, subjects from eight provinces were included in this study.

ages 15-24 (N = 278). The total number of observations is 4,741, which means that each of the 1,694 children first interviewed in 1993 participated in 2.8 waves on average.

Anthropometric measures

The first anthropometric measure is each participant's body mass index (kg/ m^2), a commonly used indicator of adiposity in epidemiologic studies (e.g., Deurenberg et al., 1991; Hu, 2008; Roche et al., 1981; Ross & Mirowsky, 1983; Y. Wang, 2001). While subjects were asked to be barefooted and wear lightweight clothing during the measurement, trained interviewers measured both weight (in *kilogram*) and height (in *centimeter*) to the nearest 0.10 unit of measurement. To examine sex, socioeconomic and regional disparities in BMI trajectories in the prevalence of underweight and overweight from childhood to adolescence, BMI cut-points for overweight and underweight recommended for international use were adopted to determine overweight and underweight status, respectively (Cole et al., 2000; Cole et al., 2007). The age- and sex-specific BMI cut-points used in the current research are based on 97,876 males and 94,851 females from birth to 25 years of age interviewed in Brazil, Great Britain, Hong Kong, Netherlands, Singapore, and the United States. The fitting method adopted by this research group restricted the fitted centile curves to pass through adult BMI cut-point for overweight of 25 kg/ m^2 and for underweight of 18.5 kg/ m^2 at age 18, and the resulting curves for both overweight and underweight across countries were averaged to provide age- and sex-specific cut-points for children and adolescents.

Since the discrete reference cut-points were given for six-month intervals, a polynomial method was adopted to provide continuous curves for screening overweight and underweight individuals. In other words, results from this polynomial interpolation can readily provide age- and sex-specific BMI cut-points for an individual's exact age. These fitted continuous curves for both overweight and underweight have achieved almost a perfect fit (See Figure 1: $R^2 > 0.999$ and the sum of squared residuals <0.05 for all four panels). After calculating each individual's exact age from date of birth and date of measurement, subjects with BMI equal to or above their age-specific criterion for overweight are identified as overweight, whereas subjects with BMI below their age-specific criterion for underweight are identified as underweight.

[Figure 1 about here]

Sex, socio-economic and regional indicators

Male is a dichotomous variable denoting the sex of each subject (male=1 and female=0), which is subsequently used to examine sex disparity in the age trajectories of BMI, overweight and underweight. Two variables measuring socio-economic status were used in the current research. *Economic advantage* is a dichotomous variable denoting whether the per capita gross income of the respondent's household fell into the top one fourth of per capita household income of the sample as a whole. *Parental years schooling* is a continuous variable denoting the average years of schooling of parents. Next, three measures of regional disparity were employed to examine their association with BMI, overweight and underweight. *Urban China* is a dichotomous variable denoting whether a household lived in an urban area in 1993. Due to China's rural-urban divide, living in urban areas in the pre-reform era defined a person's entitlement to a varieties of social and economic resources, such as education, health care and housing (Fu & Ren, 2010; Wu & Treiman, 2007). Given that salient difference in the prevalence of underweight between southern and northern China has been reported elsewhere (Doak et al., 2002), *Southern China* is a dichotomous variable denoting whether a household lived in the southern part of China. *Eastern & Middle China* is a dichotomous variable denoting whether a household lived in the middle or eastern part of China. Compared with middle and eastern regions, western region has been underdeveloped and its economic growth lagged behind other regions, which is manifested by the national go-west campaign launched in 1999. All these socio-demographic variables refer to the first wave of CHNS (the 1993 wave) examined in the current study and this strategy has been adopted by other similar studies using growth curve analyses (e.g., Danner, 2008; Harris et al., 2009; Howe et al., 2011). Finally, the age (square) of subjects at different survey waves and survey waves are included in the models.

Statistical analysis

Growth curve modeling is employed to examine the sex, socioeconomic and regional disparities in age trajectories of BMI, underweight and overweight. To capture curvilinear BMI growth during childhood and adolescence (Cole et al. 2000), a second order of age (acceleration) was also included. Using a two-stage model formulation of hierarchical linear models (Raudenbush and Bryk 2002), this growth curve model can be expressed as follows:

Level-1 model:

$$BMI_{ij} = \pi_{0i} + \pi_{1i} \times age_{ti} + \pi_{2i} \times age_{ti}^{2} + \varepsilon_{ti}$$

Level-2 models:

Intercept
$$\pi_{0i} = \beta_{00} + \sum_{q=1}^{Q} \beta_{0q} X_{qi} + r_{0i}$$

Slope
$$\pi_{1i} = \beta_{10} + \sum_{q=1}^{Q} \beta_{1q} X_{qi} + r_{1i}$$

Acceleration
$$\pi_{2i} = \beta_{20} + \sum_{q=1}^{Q} \beta_{2q} X_{qi} + r_{2i}$$

Meanwhile, these models above can be represented by a single formula using the interactions between age (square) and other variables:

$$
\begin{aligned}
BMI_{ij} &= (\beta_{20} + \sum_{q=1}^{Q} \beta_{2q} X_{qi} + r_{2i}) \times age_{ti}^2 + (\beta_{10} + \sum_{q=1}^{Q} \beta_{1q} X_{qi} + r_{1i}) \times age_{ti} + \sum_{q=1}^{Q} \beta_{0q} X_{qi} + \beta_{00} + r_{0i} + \varepsilon_{ti} \\
&= \beta_{20} \cdot age_{ti}^2 + \beta_{10} \cdot age_{ti} + \sum_{q=1}^{Q} \beta_{0q} X_{qi} + (\sum_{q=1}^{Q} \beta_{2q}) \cdot X_{qi} \cdot age_{ti}^2 + (\sum_{q=1}^{Q} \beta_{1q}) \cdot X_{qi} \cdot age_{ti} + \beta_{00} + r_{2i} \cdot age_{ti}^2 + r_{1i} \cdot age_{ti} + r_{0i} + \varepsilon_{ti}
\end{aligned}
$$

The variance-covariance matrix for level-2 random effects is given as below, where τ_{ij} ($i \neq j$) is not restricted to be zero in the estimation to account for dependence among random components.

$$
T = \begin{bmatrix} \tau_{00} & \cdot & \cdot \\ \tau_{10} & \tau_{11} & \cdot \\ \tau_{20} & \tau_{21} & \tau_{22} \end{bmatrix}
$$

Based on the age- and sex-specific cut-points for overweight and underweight generated by the aforementioned polynomial method, prevalence of overweight and underweight from childhood to adolescence (age 6-16) were predicted by hierarchical logistic models using the same set of independent variables and estimation strategy, except for the fact that insignificant random components at the level-1 slope and acceleration were omitted to achieve statistical convergence. A three-point moving-average data-smoothing process has been applied to predicted prevalence.

RESULTS

The characteristics of the 1,694 subjects interviewed aged 2-11 in 1993 are shown in Table 1. These subjects had an average BMI of 15.792 and were, on average, 6.856 years old. More than one half of these children were boys (53.8%). This is not surprising given the fact that imbalanced birth sex ratio in China has been a focus of demographic research for decades (Zeng et al., 1993). Less than 20 percent of these children came from high-income families and the average years of schooling of their parents were 7.198 years. Children resided in urban China contributed to about 20% of the sample surveyed in

1993. The majority of children lived at the southern part of China. About 30% of these children were interviewed at western China.

[Table 1 about here]

With regard to the trajectories of BMI over childhood, results obtained from growth curve models are shown at Table 2. As suggested by the Model 1 in Table 2, both age and age square have significant effect on BMI, while the average BMI in 1997, 2000 and 2004 were higher than that in 1993, net of other effects. [2] When a series of socio-demographic indicators are included in the Model 2, virtually all of them have significant effect on the BMI (except for urban residence). Net of other effects, male and subjects from high-income families tend to have higher BMI, whereas subjects with higher parental years of schooling or located at southern or western China show lower BMI. Yet, if we take into account of the interactions between age (square) and these indicators in Model 3, not only the significant main effect of age (square) on BMI no longer hold but several coefficients of these socio-demographic indicators (such as high-income families and southern China) reverse signs. Meanwhile, the main effect of parental years of schooling on BMI is non-significant. Except for the interactions between age (square) and male and the interaction between age and eastern & middle China, most of these interactions between age (square) and socio-demographic indicators are significantly associated with BMI. The age trajectories in BMI increased significantly faster for children from high-income families and urban China, but slower for children having higher parental years of schooling or residing at southern China. However, the growth of age trajectories in BMI accelerates for children having higher parental years of schooling or residing at southern China, but decelerates for children from high-income families or locating at urban China or western China. Finally, the validity of taking into account the dependence of random components during

[2] The non-significant result of the 2006 wave is possibly due to insufficient number of subjects traced in 2006 (N=278).

estimation is supported by the significant off-diagonal elements in the variance-covariance matrix from Model 1 to Model 3.

[Table 2 about here]

To examine the implications of age trajectories in BMI on childhood overweight and underweight, we further predicted age trajectories of the prevalence in overweight and underweight in the transition from childhood to adolescence (age 6-16). Based on the underweight and overweight status produced by a polynomial method, predicted results are generated by multilevel logistic analyses with the same set of covariates and model configuration at Model 3 in Table 2 (see Figure 2). Across different demographic, socio-economic and geographic groups, the prevalence of underweight grows steadily from age 6 to age 12, then either levels off or declines afterwards. By and large, the age trajectories in the prevalence of overweight show a long-term decline, though the decline slows down or be reversed around age 12. With regard to age trajectories of specific socio-demographic groups, females' prevalence of underweight is consistently higher than that of males. Although males also have higher prevalence of overweight than that of females, the sex disparity in overweight is mild until age 12 when the sex difference in the prevalence of overweight widens up. Children from high-income families have lower prevalence of underweight and higher prevalence of overweight than children from medium- and low-income families do and the gap enlarges for older children, while such socioeconomic disparity in age trajectories of underweight is greater than that in overweight. There is virtually no difference in the age trajectories of overweight for children having different parental years of schooling.[3] Likewise, the educational disparity in the age trajectories of underweight is barely noticeable until age 12.[4]

With regard to regional disparities in age trajectories of overweight and underweight, the prevalence of underweight for children in urban China shows a steady decline from age 6 to age 16, whereas the prevalence of underweight for their peers in rural China dramatically increases from age 6 to age 12 and then decreases afterwards. Although urban children have higher prevalence of overweight than their peers in rural China, the age trajectories begin to converge around age 13. Over the age interval of study, children living at southern China and western China have consistently higher prevalence of underweight and lower prevalence of overweight than their peers living at northern and middle & eastern China, respectively. However, such salient gaps in the prevalence of underweight among children located at different geographical locations in China (south versus north, west versus middle & east) tend to decrease after age 12.

DISCUSSION

In this research, the sex, socioeconomic and regional disparities in BMI trajectories across childhood are examined using growth curve models. Net of other effects, results show that boys and children from high-income families are significantly associated with higher BMI, whereas children with higher parental education, living in southern or western China are significantly associated with lower BMI. Moreover, the significant main effect of age and age square on childhood BMI can be explained by interactions between age (square) and these socio-demographic variables. Based on a polynomial method

[3] We also tried different cut-off points for parental years of schooling, such as 7 years or 9 years but the education disparity in age trajectories of overweight remains unclear.

[4] Given the fact that the predicted prevalence is generated by multilevel logistic analyses using the same model configuration as Model 3 in Table 2, the trivial educational disparity in age trajectories of both overweight and underweight is consistent with the non-significant main effect of parental education shown in Table 2.

and logistic growth curve analyses, we further examine the implication of BMI trajectories on underweight and overweight in the transition from childhood to adolescence (age 6-16). Although parental education has little effect on age trajectories of overweight or underweight, boys and children from high-income families are associated with lower prevalence in underweight and higher prevalence in overweight. Meanwhile, salient regional disparities in age trajectories of underweight and overweight have been observed. Children from urban areas, northern or western China are significantly associated with higher prevalence in overweight, whereas their counterparts (children from rural areas, southern or non-western regions) are significantly associated with higher prevalence in underweight.

The sex disparity in age trajectories of BMI, underweight or overweight is not surprising given the strong preference of boys over girls in Confucian culture because sons, instead of daughters, are more relevant to the continuation of family lines, the intergenerational transfers of property rights and the living arrangements of older parents (Lee & Wang, 2001; Poston Jr. et al., 1997). Whereas the income disparity in age trajectories is expected as high-income families have better access to nutrition than others, the invisible educational disparity in age trajectories of overweight and underweight suggests that knowledge of public health, especially that relevant to overweight and underweight, has not been incorporated in formal education in China (Kan & Tsai, 2004). Consistent with results from existing studies (Doak et al., 2000; Luo & Hu, 2002), our results point to the significance of China's rural-urban divide in shaping childhood underweight and overweight. Since China adopted the Soviet Russia's model of prioritizing urban industrial growth at the cost of rural development in the early 1950s, the socialist state's bias towards urbanites and its development ideology that rural persons should be self-reliant have deprived rural persons' access to a variety of social benefits and state resources, such as subsidized food, health care and social welfare (Chan & Zhang, 1999; Wu & Treiman, 2007). As energy intake is not catching up with rural children's physical growth, a dramatic increase in the prevalence of underweight has been observed for rural children from age 6 to age 12, whereas the prevalence of underweight for their urban peers show a steady decrease over the same age interval. While the prevalence of underweight for both rural and urban children declines after age 12, the convergence of their prevalence of overweight may be attributed to the massive rural-urban migration as rural children are approaching adulthood (J. Chen, 2011; B. Wang et al., 2010). Finally, the salient differences in the prevalence of overweight and underweight between children from western China and middle & eastern China is expected given the fact that economic and social development in western China seriously lagged behind other regions in China (Grogan, 1995), while different dietary patterns may account for the south-north differences in childhood underweight and overweight (Doak et al., 2002; Zhou et al., 1994).

With regard to the implications of the current study, it suggests that the dual burden of nutritional problems in reform-era China is more of flip sides of a coin than two separate health issues. For a specific socio-demographic group, children who have lower prevalence of underweight in the transition from childhood to adolescence (such as boys, children from high-income families, children living in urban China, etc.) also exhibit higher prevalence of overweight than their counterparts do. As demonstrated by the age trajectories of underweight and overweight, the children aged 6 to 12 are more to the increase in the prevalence of underweight, whereas older children who are at the age for secondary education are more vulnerable to that of overweight. Although these results does not necessarily mean the focus of intervention programs should be shifted from underweight in primary schools to overweight in secondary schools in China, policy makers, health workers and school teachers should be aware of the critical periods for intervening childhood underweight and overweight, respectively. Last but not the least, given the fact that salient regional disparity and striking economic inequality exist in China, the influence of regional indicators, instead of being treated merely as control variables, on health outcomes deserves serious attention. This study demonstrate that unequal allocation of social, economic and health resources across different areas in China is a key factor driving the distribution of overweight and underweight. A person's geographical location in China shapes, if not determines, his/her access to a variety of resources and exposure to certain health outcomes.

TABLES AND FIGURES

Table 1 Characteristics of the study sample in the 1993 wave of the CHNS (N=1,694)

	Mean	S.D.
Body Mass Index	15.792	2.220
Age	6.856	2.393
Male	53.8%	
High-income families	18.5%	
Parental years of schooling	7.198	3.098
Urban China	19.9%	
Southern China	64.2%	
Eastern & Middle China	70.6%	

Table 2 Growth curve models on BMI trajectories of children and youth in China: 1993-2006

	Model 1		Model 2			
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Level-1 intercept						
Age	-0.408	0.043***	-0.391	0.043***	0.130	0.135
Age square	0.031	0.002***	0.031	0.002***	0.010	0.006
Waves of survey (the wave of 1993 as the reference group)						
The 1997 wave	0.345	0.104**	0.342	0.102**	0.355	0.102***
The 2000 wave	0.785	0.154***	0.731	0.149***	0.727	0.149***
The 2004 wave	1.124	0.259***	1.063	0.251***	1.035	0.251***
The 2006 wave	0.340	0.347	0.275	0.338	0.220	0.338
Male			0.204	0.086*	0.917	0.343**
High-income families			0.315	0.115**	-1.413	0.460**
Parental years of schooling			-0.034	0.015*	0.108	0.060
Urban China			0.168	0.117	-1.097	0.472*
Southern China			-0.585	0.102***	1.401	0.406**
Eastern & Middle China			0.577	0.106***	1.396	0.429**
Intercept	16.909	0.201***	16.829	0.265***	14.118	0.693
Level-1 slope						
Male					-0.124	0.068
High-income families					0.290	0.091**
Parental years of schooling					-0.031	0.012**
Urban China					0.269	0.094**
Southern China					-0.364	0.082***
Eastern & Middle China					-0.145	0.085
Level-1 acceleration						
Male					0.004	0.003
High-income families					-0.009	0.004*
Parental years of schooling					0.001	0.001**
Urban China					-0.012	0.004**
Southern China					0.013	0.004***
Eastern & Middle China					0.005	0.004***
τ_{11} (age)	0.278	0.062***	0.284	0.063***	0.221	0.060***
τ_{22} (age square)	0.001	0.000***	0.001	0.000***	0.001	0.000***
τ_{00} (intercept)	3.944	1.434***	4.581	1.472***	3.079	1.371***
τ_{21} (age, age square)	-0.012	0.003***	-0.012	0.003***	-0.010	0.003***
τ_{10} (age, intercept)	-0.918	0.293**	-1.025	0.298***	-0.723	0.281*
τ_{20} (age square, intercept)	0.038	0.013**	0.042	0.013**	0.031	0.012*
σ_{ε}^2 (residual)	3.334	0.118***	3.295	0.117***	3.361	0.119***

Note: Statistical significance: * $p < 0.05$; ** $p<0.01$; ***$p<0.001$ (two-tailed tests);

For the Model 1 in Table 1, the unexplained variance σ^2 is 4.394 (.111) in the absence of random effects in slope and acceleration and 6.454 (.133) in the absence of any random effects.

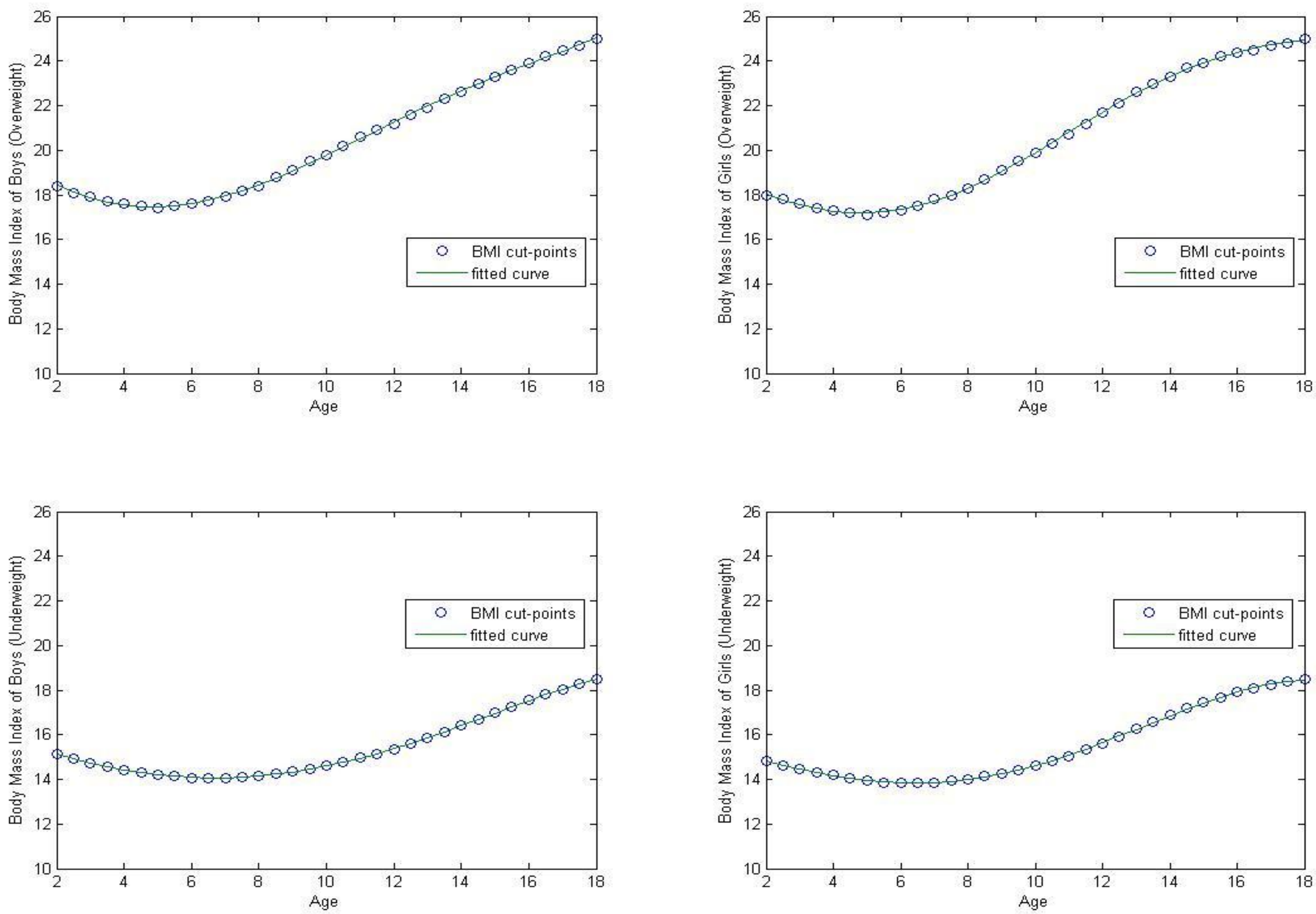

Figure 1 Fitting the age- and sex-specific cut-points for overweight and underweight by a polynomial method

(R^2 > 0.999 and the sum of squared residuals <0.05 for all four figures)

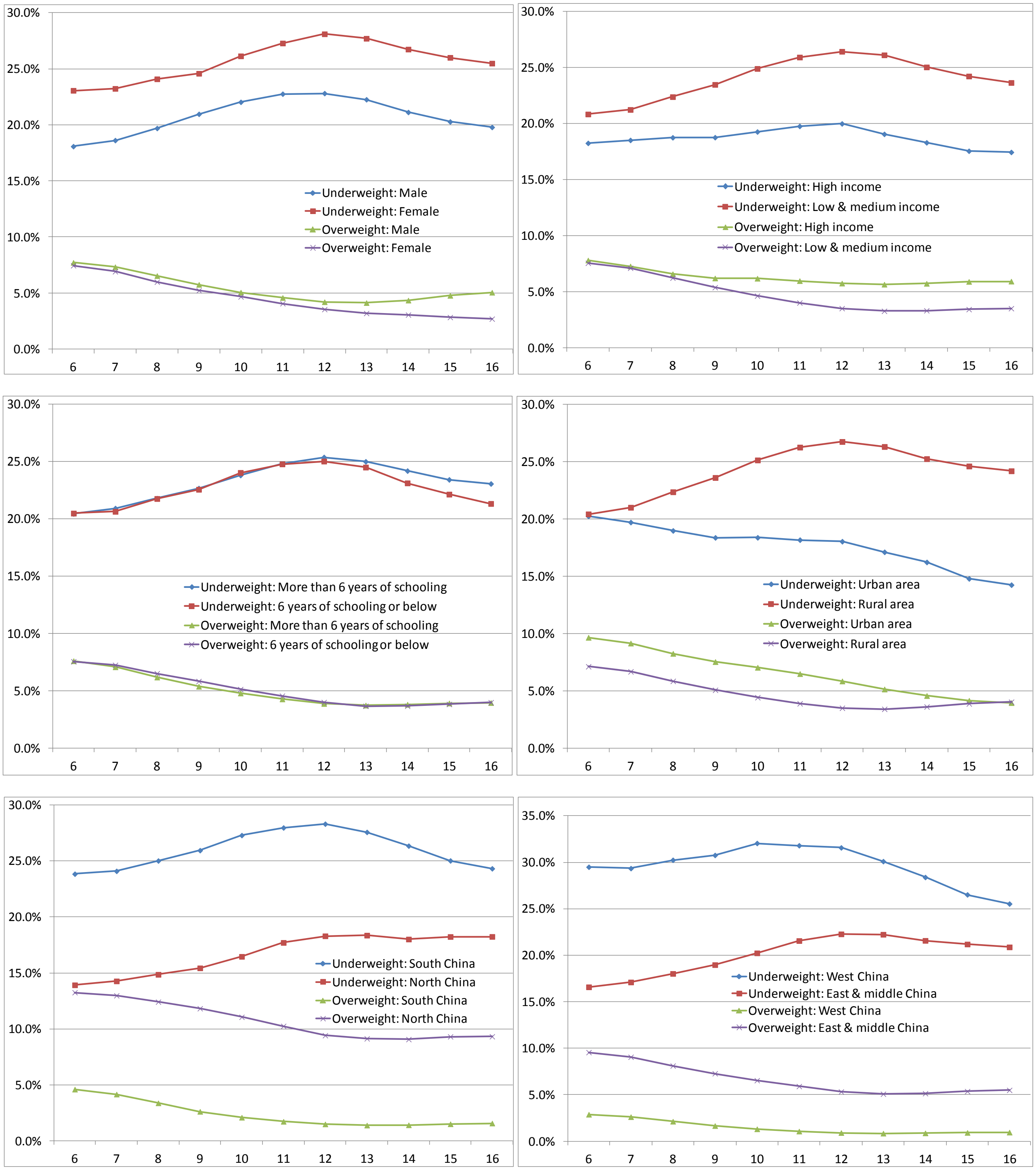

Figure 2 Age trajectories of the prevalence in overweight and underweight as moderated by sex, socioeconomic status and regional disparity (children and youth aged 6- 16)

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