Distribution Agreement

Signature:

______________________________ _______________

Xu Ji Date

The Effect of Active School Transportation on Childhood Obesity Prevention in Chinese Students

By

Xu Ji
MSPH

Health Policy and Management

Jason M. Hockenberry
Committee Chair

Laura M. Gaydos
MSPH Director

Peter J. Joski
Committee Member

The Effect of Active School Transportation on Childhood Obesity Prevention in Chinese Students

By

Xu Ji

MA, Health Administration
Nanjing Medical University, Nanjing, China
2012

Thesis Committee Chair: Jason Hockenberry, PhD

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Science in Public Health
in Health Policy and Health Services Research
2013

Abstract

The Effect of Active School Transportation on Childhood Obesity Prevention in Chinese Students

By Xu Ji

There is an a trend of increasing trend of childhood obesity and decreasing active school transportation (AST) among Chinese student during the most recent 15 years, due to the rapid urbanization and Westernization. One theorized solution is to refocus on AST promotion in China; however, no clear evidence exists on whether AST is likely to be successful in reducing obesity among Chinese children and adolescents, and how this varies among different student sub-populations. This study examined the relationship between AST and childhood obesity in a recent population-based sample of Chinese students using the 1997-2009 China Health and Nutrition Surveys (n=3,932). Using random and fixed effects methods, I examined the likelihood of being overweight and obese in LPMs and the BMI z-score in OLS models, when controlling for AST time, school location, community urbanization indices, and household and individual characteristics. I then re-estimated every model and added an interaction composed of AST time and school location. There was no significant independent effect of AST time among all students, but a significant interaction effect of AST and school location on obesity and overweight. Among students whose schools were located within their communities, they were less likely to be overweight and obese, if they spend more AST time. In conclusion, AST is effective at reducing obesity for students whose schools are within their communities, but insufficient to address the overall childhood obesity problem in China. Future interventions should emphasize and promote AST, specifically targeting students whose schools are within community.

Acknowledgement

To my parents: Thank you for supporting me on my journey into research and for encouraging me to do what I love. Mom and Dad, you have served as nothing but the greatest role models for me. Your energy gives me my momentum.

To my mentors, Dr. Hockenberry, Dr. Gaydos, and Peter: I would not be where I am today without you. Thank you so much for your mentoring and patient help through the two years. You taught me to be open-minded, diligent, principled, and passionate about this field and I hope to be your colleague in it for years to come.

To my MSPHers past and present: Your support, keen critiques, and smiling faces have been an absolute joy to learn and grow with over the past two years. I wish nothing but the best for you and hope we can remain close friends and colleagues as the years roll by.

Finally, this research uses data from the China Health and Nutrition Survey (CHNS). I thank the National Institute of Nutrition and Food Safety, China Center for Disease Control and Prevention; the Carolina Population Center, University of North Carolina at Chapel Hill; the National Institutes of Health (NIH; R01-HD30880, DK056350, and R01-HD38700); and the Fogarty International Center, NIH, for financial support for the CHNS data collection and analysis files since 1989. I thank those parties, the China-Japan Friendship Hospital, and the Ministry of Health for support for CHNS 2009 and future surveys.
(The last paragraph of this acknowledgement is officially required by CHNS for data use.)

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AST	Active School Transportation
BMI	Body Mass Index
CHNS	China Health and Nutrition Survey
FE	Fixed Effects
FM	Fat Mass
LPM	Linear Probability Model
RE	Random Effects
PA	Physical Activity
SES	Socioeconomic Status

1. Introduction

Whereas the growth of overweight and obesity in the U.S. and Europe has been recognized for several decades, in China this is an evolving phenomenon due to rapid trends in urbanization and westernization. Actively commuting, walking or bicycling, to and from school – active school transportation (AST) -- is one physical activity domain that has been recommended as an important source of daily physical activity and overweight/obesity prevention among school children and adolescents. Recently, international initiatives to promote AST among school children have been suggested. Many studies have been conducted to explore the association between AST and childhood obesity in U.S., Europe and Australia. In China, AST has traditionally been more common than in western countries; however, due to the increasing sedentary lifestyle, the prevalence of active commuting patterns has decreased while childhood overweight/obesity has steadily increased. One proposed, theorized solution is to refocus efforts to increase AST, but very few studies have been conducted on whether this is likely to be successful in reducing childhood obesity, and how this varies in different student sub populations in China, where the population has different lifestyles and challenges compared to that in western countries.

This study seeks to answer whether actively commuting to school is likely to prevent childhood obesity among Chinese school students, and whether all students will be impacted equally or if this will vary for sub population groups.

2. Literature Review

Obesity

The growing prevalence of obesity among adults and youth has become one of the major health concerns worldwide [1-4]. Obesity is second only to smoking as a contributor to mortality [5]. Excess weight in childhood is associated with an array of adverse physiological and psychosocial conditions [6], as well as increased morbidity and mortality in adulthood [7]. Childhood obesity is also a contributing factor for Type2 diabetes and cardiovascular disease. Moreover, childhood obesity and its adverse health consequences may persist to adulthood [7]. Much of the growing overweight/obesity epidemic is due to sedentary lifestyle, such as TV viewing, private motor vehicle use [8-11], and reduced participation in physical activity (PA) leading to decreased daily energy expenditure [12-14].

In the U.S., an increase in the prevalence of obesity in both children and adults has continued unabated over the last two or three decades [15], and over 10% of children and 50% of adults are overweight [16]. The direct economic cost of illness in the U.S. associated with a lack of physical activity has been conservatively estimated at $24 billion and the cost of obesity at $70 million [17]. Thus, promoting youth activity may be the principle strategy needed to protect children from excessive weight gain [18, 19], and may produce a basis for long-term maintenance of an active adult lifestyle [20-22].

Until recently, the interest in childhood obesity mainly comes from the U.S. and other developed nations. There has been little research focused on childhood obesity in developing nations. However, the rapid urbanization and globalization processes, coupled with nutritional and demographic transitions, have recently been linked to the obesity epidemic in low- and middle-income countries [23]. Some developing countries, including China, are in the midst of a rapid shift in diet and physical activity patterns that are linked with greater obesity and related problems. There is evidence of rapid declines in physical activity and increases in dietary-fat intake in China [24, 25]. Of particular concern is that among Chinese children, the prevalence of overweight and obesity has increased steadily over the past 15 years [26].

The most noticeable increase in overweight and obesity prevalence was in Chinese children from urban areas and those with higher income backgrounds [26]. By 2000, the prevalence of childhood obesity and overweight in the coastal cities of China had reached the level found in developed countries, while prevalence was still low in most of the inland cities [27]. From 1991 to 2006, the mean Body Mass Index (BMI) of Chinese youth aged 7-17 years increased from 17.4 to 18.3 kg/m^2, with a corresponding increase in the prevalence of overweight from 5.2% to 13.2% [26]. Kim et al. indicated that children in high socioeconomic status (SES) groups have better access to energy-dense foods and labor-saving machines, which in turn leads to energy imbalance [28, 29]. Moreover, under the one child policy in China, the single child is a focus of attention of both parents and grandparents, which may contribute to the overfeeding of children [30]. In contrast, Chinese children in low SES groups are more physically active. However, studies in developed countries showed that lower SES children may have more opportunities to be exposed to the factors causing obesity [31]. This may suggest that the burden of obesity may gradually transfer from populations with higher SES to those with lower SES in developing countries if no effective intervention measures are taken [26].

Active School Transportation (AST)

One potential way to minimize the reduction in physical activity for individuals is to maximize their opportunities for incidental physical activity, such as walking to school or work [9]. Evidence has shown that, among Chinese adults, going to and from work by walking or bicycle was found to reduce the risk of being overweight by 50% compared with going by bus [32, 33]. However, this relationship has not been examined among Chinese youth.

Establishing physical activity behaviors early in life may establish healthy habits that can be carried on into adulthood. One such behavior is active school transportation (AST), defined as travel between home and school by walking, cycling, and other non-motorized means of transportation. The journey to school provides an opportunity for increasing daily physical activity and potentially preventing excess weight gain among school-aged youth [34]. Literature has shown that children and adolescents who walk or bicycle to school have higher daily levels of physical activity and are more likely to meet physical activity recommendations than are youth who travel to school by car or bus [41]. These effects are noted when both self-report [35-37] and objective [37, 38] measures of physical activity are used and are evident among elementary- [35], middle- [37, 38], and high-school-aged [36] children, in the U.S., Europe, and elsewhere [39, 40]. Children who actively commute to school have also been found to have better cardiovascular fitness than their non-active counterparts [41]. A Danish study reported that youth who cycled to school were on average more physically fit than those who walked or used motorized forms of transport [34]. In a Scandinavian study, isometric muscle endurance (10–16%), dynamic muscle endurance in the abdominal muscles (10%), and flexibility (6%) were higher in the cyclists [42]. Therefore, AST has been suggested as an important and regular source of physical activity for youth, especially as time spent on physical activity in school declines [43].

However, rates of AST have declined precipitously during the past 30 years [41]. In the U.S., children walk or bike to school and other places less than they did 20 to 30 years ago [43]. In 2001, less than 16% of children aged 5 to 15 actively commuted to school, compared with 48% in 1969 [41]. In Germany, between 1976 and 2002 the proportion of all trips made by walking or cycling decreased from 43 to 31% [44]. Notably, however, all of this literature comes from developed nations.

In contrast with western countries, cycling and walking remain the dominant forms of transportation in China [32, 33]. However, passive commuting modes have increased over the past decade, due to rapid urbanization and increases in the availability of motorized vehicles. Studies have reported that AST prevalence of Chinese children decreased more than threefold from 1997 to 2006 [45]. This decline appears to coincide with the increasing household SES and household motorcycle ownership. Increased affluence and competition also suggest that parents may choose to drive their children further to a school with a better educational reputation, partially explaining the increasing passive commuting. These are especially true in northern and eastern regions of China with a higher socioeconomic status compared to Western China. Additionally, this trend also coincides with a decline in total number of schools, resulting in fewer communities with a school inside the community, and thus increased trip distances to school.

Thus, preventive programs have been suggested to refocus on AST and, especially, to target students whose schools are within a walkable or bikeable distance, to encourage walking or cycling to school [46]. However, there has been little systematic examination into the potential for AST to reduce overweight or obesity among youth in China [41].

Effect of AST on Childhood Obesity

Among existing studies which examines the relationship between AST and childhood obesity, the results have been inconsistent [47]. Little evidence exists linking AST to reduced BMI among school-aged youth [41].

Many studies in developed countries have shown an insignificant association between AST and childhood obesity. Fulton et al. [48] observed no significant association between AST and body weight status in a cross-sectional study among a national sample of boys and girls in grades 4 through 12 in the U.S. However, they could not make a conclusion on the causal effect of AST due to the cross-sectional study design. Similarly, Landsberg et al. did not find a significant association between AST use and fat mass (FM) or BMI either, among a group of 14-year-old adolescents in Germany [49]. In this study, however, there was a significant interaction between distance to school and FM, suggesting that FM decreased as distance from school increased in active commuters [49]. This study was one of the few studies which considered the distance to school while exploring the association between AST and obesity.

One study of individuals in the U.S. did find a significant association between AST and body weight status, but with an unexpected positive direction [35].This study was conducted in a cohort of youth aged 9-11 years old in the U.S. This finding is limited by at least two important points. First, the beneficial effects of AST may be delayed because the follow-up period of the study was less than one year. Second, the results may be confounded by unadjusted factors such as SES, as a majority of their enrolled children were from lower-income families who may have an increasing likelihood of being overweight [47].

Only a few studies conducted in developed countries have found a significant effect of AST on child obesity in the negative direction predicted by theory. One longitudinal study in the U.S. on a birth cohort of children found that students who sustained AST had a lower BMI Z-score at 1^{st} and 2^{nd} grades than those who did not use AST modes or used AST intermittently using a continuous weight outcome [47]. This study focused exclusively on the impact of sustained AST on body weight among a group of young children at the early years of childhood. Another study involving adolescents in low income communities in California observed a correlation between lower reported rates of AST and higher BMI z-scores [50]. Similar findings have been reported in European studies. One study reported that normal-weight adolescents in Belgium were reported to spend more time walking or cycling to school than overweight adolescents [51]. A study of 12-year-olds in France reported that both boys and girls actively commuting to school had lower BMI and waist circumference than the active commuters [52]. Notably, all these studies were in the context of western nations, where frequency of AST is low [42].

Unlike studies of individuals in western nations, very few studies have focused on the effect of AST on obesity among Chinese. One study of residents of rural areas in China found a significant and inverse relationship between commuting physical activity and BMI among male adults [32, 33]. Another study on a cohort of adults in China reported an increase in adiposity due to the increased dependence on motorized transportation in male adults with higher social status or from rural areas [53].

Even fewer studies directly examined the relationship between AST and childhood obesity among Chinese school-aged youth [54]. One study found that students in China who walk or cycle to school were significantly less likely to be overweight than their counterparts who commute to school by bus or by car, using data from the 2002 China National Nutrition and Health Survey [54]. Notably, the results in this study were different compared to findings in some studies in high income nations. For example, by separating cyclists from walkers, this study found that Chinese walkers had the lowest odds of being overweight [54], while a Danish study reported that those cycling to school were more physically fit than those who walk [34], and in a French study, the non-active commuters were reported to be the leanest [52]. These inconsistent findings may be attributed to the differences in how SES relates to active commuting and body weight status [46] in China and in developed nations. More specifically, in China, children and adolescents from high SES or more urbanized families are less likely to actively commute to school and more likely to be overweight or obese [29]. In Western countries, however, SES and urban residence is generally negatively related to obesity [30]. Additionally, even in this study, the association between AST and body weight status was not explored as the main study objective.

Summary of Literature Limitations

First, although there is a great deal of literature on the recommendation of AST and its effect on obesity prevention in developed nations, until now, very few studies or programs have focused on the relationship between AST and childhood overweight/obesity in China, where the population has different lifestyles and challenges. More specifically, unlike western countries, AST has traditionally been more common in China; however, due to urbanization and westernization, the prevalence of AST has decreased, while childhood overweight/obesity has steadily increased. One of the proposed or theorized solutions is to refocus efforts to increase AST in order to contribute to maintaining the physical activity level among children and adolescents [45]. While this is a theorized solution, no clear evidence has been reported on whether AST is likely to be successful in reducing the growing trend of overweight/obesity among Chinese students, and how this effect varies among different student sub-populations.

Second, most existing studies were conducted using samples of individuals with very low AST frequency. Many studies were cross-sectional which limits the inference that can be drawn from the findings. Even among those studies following individuals longitudinally, most are limited by short follow-up periods. Many involved rather young children, most with a mean age below 12 years [55]; however, as the risk of being overweight/obesity increases with increasing age, the association between AST and childhood obesity may be more prominent among adolescents aged 13-18 [56, 57].

It is also notable that the modeling strategies in existing studies may be incomplete. The process by which obesity develops is, in fact, complex and implicates several lifestyle and genetic determinants [52]. Walking or cycling to and from school reflects environmental and socioeconomic constraints, but these are also potentially related to family culture and biology. Thus, the results of some studies may be biased because of the unobserved or unmeasured variables, such as household preferences for health and health investment, as well as genetic factors. Even for those studies that did adjust for parental body weights-- a proxy of genetic determinants and/or household preferences for health and health investment [58], a substantial amount of health outcome variances still remained unexplained due to the effect of other confounders [52]. Other unexplained or partially explained variables may include: urbanization levels, preferences of dietary and physical activity, and so forth. Additionally, few studies have considered the distance from home to school as a modifier; however, the commuting behaviors and the related effects on obesity prevention may be different in youth living within a shorter or longer distance from school.

Therefore, this study adds evidence to studies in China and provides insight into the relationship between AST and childhood overweight/obesity among youth aged 6–18 years old, using a more robust analytic approach, in order to fill in the gaps in literature. This study fills a void in the evidence base which should help to make recommendations concerning whether the promotion of AST is likely to be an effective intervention to reduce childhood obesity.

3. Methods

Research Questions and Hypothesis

Q1: Are students who spend more time on AST less likely to be overweight or obese, in China?

H1: Students who spend more time on AST are less likely to become overweight or obese in China.

Q2: Will all students be impacted equally or vary for sub population groups?

H2: AST effect is higher among students whose schools are located within their local communities compared to those whose schools are outside of their communities.

Data Source

The data are from the 1997, 2000, 2004, 2006, and 2009 China Health and Nutrition Survey (CHNS). The CHNS is a longitudinal survey that was originally designed to examine how the social and economic transformation of Chinese society (i.e., national and local implementation of health, nutrition, and family planning policies and programs) has affected the health and nutrition status of its population. CHNS covered eight provinces in 1997 and nine provinces in 2000, 2004, 2006, and 2009 (Guangxi, Guizhou, Henan, Hubei, Hunan, Jiangsu, Liaoning, Heilongjiang, and Shandong provinces). These provinces vary substantially in geography, economic development, and health indicators. In addition, since 1997, new households in the original communities have been added to replace households no longer participating in the study.

The China Health and Nutrition Survey employed a multistage random-cluster sampling procedure in each province. Counties in the eight provinces were initially stratified by income (low, middle, and high) and a weighted sampling scheme was used to randomly select four counties in each province. The provincial capital and a lower income city within each province were selected. Within each city, urban and suburban neighborhoods were randomly selected. In addition, the township capital and three villages within the counties were randomly selected. Finally, twenty households were randomly selected within each neighborhood, and all individuals in each household were interviewed. For youth 6-18 years of age, older children were asked survey questions directly and parents were present for interviews with children younger than 10 years of age and often assisted the child or answered the questions directly as a proxy for the child.

Based on the CHNS definition of communities, villages and townships within the counties and urban and suburban neighborhoods within the cities were selected randomly into primary sampling units (PSUs), which they defined as 'communities'. In order to collect data at the community level, leaders of villages or communities were interviewed using the community questionnaire. The neighborhoods and villages were defined politically and geographically based on the communist party definitions.

All the individual and household level data of CHNS are publicly available, but the community level data are restricted [59]. A data release contract was drafted to securely release the de-identified dataset to the study team. The dataset contained community level information related to this study, specifically access to public schools in the local community. This study was reviewed and received exempt approval by Emory Institute Review Board, #IRB00061189 on 10/10/2012.

Study Design and Subjects

The comprehensive data from the most recent five waves of CHNS are treated as unbalanced panel data and only individuals who were followed up at least twice were included in this study. Based on longitudinal data, I conducted secondary data analysis to predict changes in indicators of obesity, dependent on transportation modes to school among Chinese students. More specifically, I conducted trend analyses to show the changes in both AST and childhood status of being overweight or obese in China, as well as regression analyses to examine whether AST actually predicts overweight/obesity status when controlling for community urbanization indices, environmental factors, and related household and individual information. The presence of schools within community was used as the main modifier for sample stratification in order to explore how results vary among subpopulations.

For this analysis, I excluded some of the observations for various reasons. Figure 1 documents the inclusion criterion used to create the final sample. First, I obtained 9,789 observations from all school children and adolescents enrolled in 1997, 2000, 2004, 2006, and 2009 CHNS. Next, I removed 2,526 individuals who were only repeated once across the five waves and 2,523 observations with incomplete information on any of the dependent or independent variables. Then, I removed 808 observations from individuals who only repeated once after deleting observations with missing value of any of the variables used in regression models. Finally, 3,932 observations from 1,698 students aged 6-18 who have detailed and complete information on all variables in the analysis were included in this study.

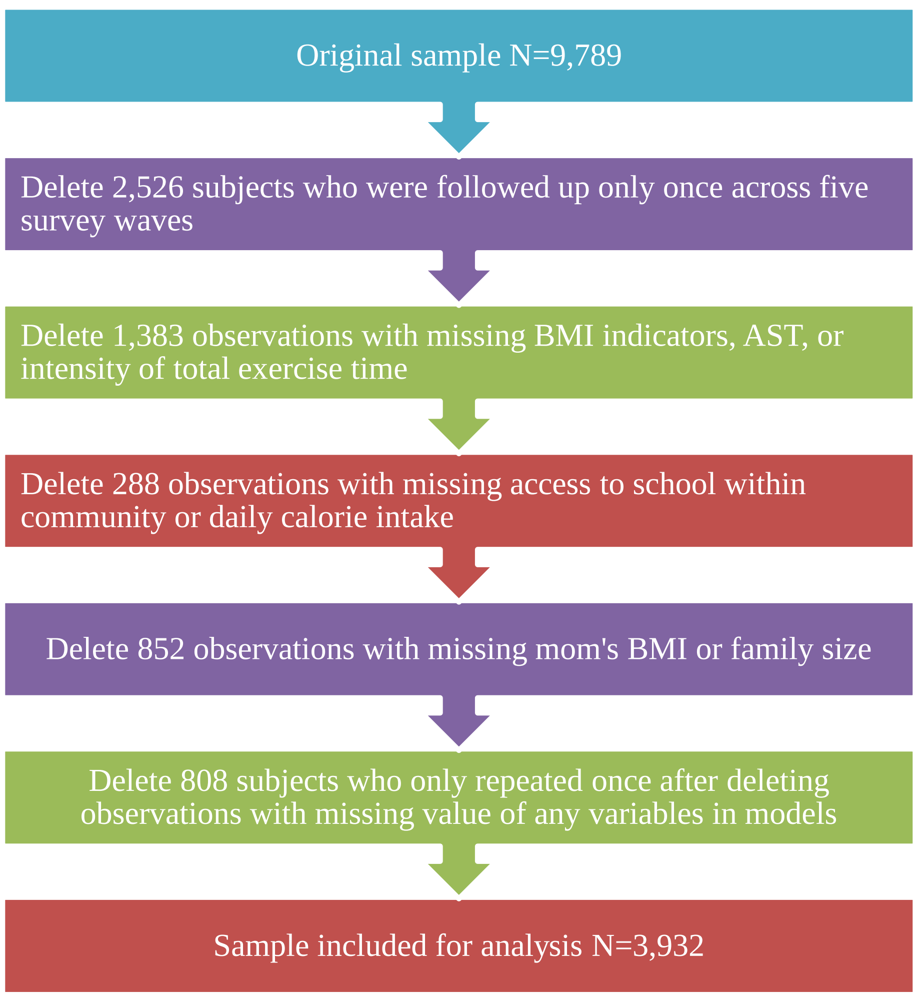

Figure 1. Inclusion Criterion of Sample for Analysis

Data Analysis

Dependent variable – Indicators of Obesity

The information on weight and height are directly available from the CHNS dataset. Body Mass Index (BMI) was calculated as weight in kg/(height in meters)^2. Childhood overweight or obesity status were defined as age- and gender-specific BMI 85th and 95th percentile, respectively, in accordance with age- and sex- specific Chinese BMI cut-offs recommended by the Working Group on Obesity in China (WGOC) (Group of China Obesity Task Force, 2004). In this study, overweight was defined as equal to or greater than age- and gender-adjusted BMI 85th percentile, with underweight or normal weight as the comparison. Obesity status was defined as equal to or greater than age- and gender-adjusted BMI 95th percentile; underweight, normal weight, and overweight were the reference. Additionally, I used the age- and gender-adjusted BMI z-score as another outcome.

Independent variable -- School Commuting Modes

In the children's questionnaire there were two questions asked about walking, bicycle use, and motorized transportation: “Do you travel to and from school this way?” and “How long does a round trip take?” In 1997 and 2000 CHNS questionnaires, motorized transportation included bus and subway, while from 2004 to 2009 car, taxi and motorcycle use were added to reflect changes in transportation modes used throughout China. Additionally, from 2004 to 2009, bicycle use was separated into two independent variables to specify actually pedaling or being a bicycle passenger.

In this study, participants were categorized as actively commuting to and from school, if they answered walking or pedaling in 2004, 2006 and 2009. It is not typical for Chinese children under 12 years of age to ride a bicycle on their own. Thus, for data from 1997 and 2000 surveys, children under the age of 12 who reported commuting to and from school by bicycle were not characterized as active commuters, because they were most likely to be passengers on parents’ bicycles. Duration of actively commuting to and from school each week was calculated by multiplying reported time of a round trip on a typical day, by 5 days per week. The duration was calculated as “0” for non-active commuters.

The measurement of AST in this study is the proportion of AST time among each student's total time per day, i.e.

$$[(\% \text{ AST time}) = (\text{AST time per day}/24 \text{ hours})*100].$$

This measurement helps to interpret the marginal change in outcome variables accompanied by a change in % AST time from 0 to 1 (percentage), which equals to approximately 15 minutes increase per day. The direction, magnitude, and statistical significance of the coefficient of this variable are the main interest of this study.

Covariates

<u>*Other Sources of Physical Activity*</u>

Apart from AST, CHNS also asked questions on participation and duration of physical activities inside and outside school (sports/exercise) of registered youth in school. Intensity of physical activity in and outside school was controlled for in the regression analysis. In addition, youth were also asked about performance of chores (i.e., gardening/farming/livestock care, housework, child care) and sedentary activities outside of school. Performance of chores was not necessarily queried in a consistent manner to allow for comparison. The intensity of sedentary behaviors does not necessarily contribute to energy expenditure as it is low, and the time on sedentary behavior was accounted for in total time per day in this study. Therefore, I do not incorporate performance of chores or sedentary activities in our analysis due to a large percentage of missing information, and the incompatibility with other physical activity variables.

The measures of other physical activity are provided in terms of metabolic equivalent time (MET), in hours per week, to account for both intensity of activities and time spent on activities. A MET unit is defined as the ratio of a person's working metabolic rate relative to his/her basal metabolic rate. Metabolic rate at rest is classified as 1MET, whereas 3MET activity requires three times the energy expenditure as would have been used at rest. Categories of physical activities in and outside school are considered moderate to vigorous (MOD/VIG; 3 MET) in this study. Using this calculation, an average metabolic rate value was imputed to determine the intensity of all other physical activities apart from AST in this study.

Household and Individual Characteristics

Urban or rural region is used as a dichotomous variable to distinguish regional differences, such as economic development, infrastructure, and social environment. The background and household characteristics of the sample include family size, age at each survey wave, the proportion reporting gender, and mother's BMI as a proxy of the time variant household preferences, such as preferences for fatty food, sugary drink, sedentary lifestyle, and so forth. A cutoff of 12 years of age was used to stratify analyses by age group since Chinese children leave primary school and enter middle school at this time.

Nutrition

Detailed individual dietary data are provided by CHNS. The data were collected over three consecutive days by a combination of weighing household intake of all ingredients, creating household-specific recipes for all dishes, and three consecutive 24-hour dietary recall interviews. The three-day dietary intake at the individual level has been found to be a strong measure of usual intake [25]. Methods for accounting for the measurement of condiments and oils added at the household level are quite precise [60, 61]. The key child caretaker provided data for children under age ten. Thus, the variables -- daily total energy intake (kcal/day) -- were adjusted in all regression models in this study. Smoking and drinking behaviors were not included in the analysis due to a large proportion of missing information.

Urbanization Index

Another covariate of interest is time variant and exogenous dimensions of urbanization at the community level from CHNS. The CHNS measurements of urbanization have been used in previous papers [62, 63]. Shu et al. used ten components of urbanization indices in CHNS to predict the decline in physical activity among Chinese adults from 1991 to 2006 [64]. In this study, twelve dimensions of urbanization measurements were used including: population density, economic activity; traditional markets; modern markets; transportation infrastructure; sanitation; communications; housing; education; diversity; health infrastructure; and social services. Each of the dimensions was given a score from zero to ten and was comprised of data collected from either local area administrators or official records. This metric has previously been regarded as a confounder strongly correlated with both active commuting and body weight status [65]; and the use of various dimensions of urbanization measures separates the contribution of each index and is an improvement over the classic urban–rural dichotomy that presumes homogeneity in unmeasured aspects of community environments within rural and urban settings [64, 66].

Access to School within Community

In the community level questionnaire there was a question about the location of school in each community (village): "Is there a primary school/lower middle school/upper middle school/vocational school/college in this village (neighborhood)?" Based on this question and the age of each student, the constructed variable – access to school within a student's community– was generated and regarded as a proxy of having a walkable or bikeable distance from home to school. This variable was used as the key modifier in regression analysis.

Table 1 displays a summary of all dependent and independent variables included in the analysis.

Table 1. Summary of Variables Used In Analysis

Variables	**Description**
Outcomes Variable	
Being overweight	Dichotomous variable indicating whether the subject is overweight or obese (≥85th age-, gender- adjusted BMI) or not
Being obese	Dichotomous variable indicating whether the subject is obese (≥95th age-, gender- adjusted BMI) or not
BMI z-score	Continuous: age-, gender adjusted BMI z-score
Independent Variable	
AST	
% AST time	Continuous: (Time spent on AST per day / 24 hours)*100
Actively commuting to school	Dichotomous variable indicating whether the subject walks or cycles to and from school
Walking to school	Dichotomous variable indicating whether the subject walks to and from school
Cycling to school	Dichotomous variable indicating whether the subject cycles to and from school
Modifier	
Access to school within community	Dichotomous variable indicating whether subject's school is located within or outside his(her) local community
Covariates	
Other Physical Activity	
Participation in PA in school	Dichotomous variable indicating whether the subject participates in in school physical activity
Participation in PA outside school	Dichotomous variable indicating whether the subject participates in outside school physical activity
Activity intensity from total PA in or outside school	Continuous (METs): Time per week on physical activity in, before, or after school*4 MET/h
Community characteristics	
Urbanization index	Continuous, 0-120
Population density	Continuous, 0-10
Economic activity	Continuous, 0-10
Traditional markets	Continuous, 0-10
Modern markets	Continuous, 0-10
Transportation infrastructure	Continuous, 0-10
Sanitation	Continuous, 0-10
Communications	Continuous, 0-10
Housing	Continuous, 0-10
Education	Continuous, 0-10
Diversity	Continuous, 0-10
Health infrastructure	Continuous, 0-10
Social services	Continuous, 0-10
Nutrition	
Calorie intake per day	Continuous (kcal)
Household characteristics	
Family size	Discrete
Mother' BMI	Continuous: Mother's weight (kg) / (Mother's height (m))^2
Individual characteristics	
Urban residence	Categorized as living in urban areas (coded as 1) or rural areas (coded as 0)
Boys	Categorized as boy (coded as 1) or girl (coded as 0)
Age at the baseline	Discrete

Statistical Analysis

The data analysis was conducted in three main phases. First, I stratified the sample by the availability of school within community and summarized the descriptive statistics for each variable used in regression models in each stratum.

Second, I conducted trend analysis to explored the changes across the five survey waves from 1997 to 2009 in outcomes and main exposures, including the proportions of overweight and obesity status, the proportions of active school commuters/walkers/cyclers, and the average % AST time, in order to show the unadjusted trends of AST, and overweight and obesity status, among all students and in each stratum. For categorical variables, I also conducted the Cochrane–Mantel–Haenszel test to examine temporal trends in the prevalence.

Third, to examine whether % AST time predicts obesity, I conducted regression analysis by treating the data as unbalanced panel data. I estimated linear probability models (LPM) for two binary outcome variables - being overweight and being obese, and OLS linear model for the continuous outcome -- BMI z-score. While the binary outcomes could be estimated via nonlinear models, the key independent variable of interest in many of the models is an interaction term, which is difficult to interpret in non-linear estimations [67]. Thus I used LPMs for ease of interpretation of the interaction term.

The key covariate of interest, % AST time multiplied by the availability of a school within community, was included in a version of each model. To assess whether an interaction was present, a likelihood ratio test of the regression models with and without the interaction term were conducted. All other covariates controlled for were selected based on related literature.

In my regression analyses, I addressed individual unobserved heterogeneity using person fixed (FE) and random (RE) effects methods. Although random effects models are more efficient [68], they are more likely to have biased results compared to fixed effects models (FE), due to the theorized assumption that the residual is not correlated with independent variables. In many cases, this assumption is violated [68]. Therefore, apart from random effects models, I also used fixed effects models to confirm the consistency and validity of our results. For each outcome, I conducted four regressions; FE and RE models without an interaction term and then FE and RE models with an interaction term. All analysis were conducted at a significance level of 0.05, using STATA12 (Stata Co., College Station, TX, USA) and SAS (Version 9.3; SAS Institute, Cary, NC, USA).

Regression Model

$Y_{i's} = \beta_0 + \beta_1$*% AST Time + β_2* Access to school within community

+ **(**β_3* % AST Time * Access to school within community) + β_4* Intensity of PA in and outside school + $\beta_{5's}$* Urbanization Indices + β_6* Nutrition + β_7* Household characteristics + β_8* Individual characteristics + Person Fixed (Random) Effect + Time Fixed Effect + μ_i

In these models, $Y_{i's}$ is outcomes including being obese, being overweight, and BMI z-score. In this equation, β_0 is the intercept, β_i represents the coefficients of each explanatory variable, β_3 is the coefficient of the interaction term which is of main interest, μ_i is the residual, and $\beta_{5's}$ are coefficients of the twelve urbanization indices. Additionally, nutrition is measured by daily caloric intake. Household characteristics include mother's BMI and family size, and individual characteristics include region, gender, as well as age at the base line survey.

4. Results

Descriptive Analysis

Summary Statistics

Table 2 provides the summary statistics of the key variables of interest combining data from 1997, 2000, 2004, 2006, and 2009 CHNS surveys, and stratified the entire sample by availability of school within the student's community. 1,694 observations were identified from communities without a school, while 2,238 observations were identified from communities with a school(s). On average, each student was followed up for 2.3 times.

The proportions of overweight and obese students are 8.9% and 3.1%, respectively, among students whose school is located within their community; this is higher than the proportions for students whose school is not located within their community. Additionally, there is no significant difference in the average BMI z-score between the two student groups.

The average percent of active commute time in total time per day, the key explanatory variable, is 1.03%, approximately 15 minutes per day, among students whose school is available within their community, which is significantly lower than that for their counterparts. Among students whose school is located within their community, the proportion who actively commute (walk or cycle) to school is 95.0% while the proportion who walk to school is 84.6%. These proportions are both significantly higher than those of their counterparts. However, the proportion of cyclers among students whose school is within their community is 8.9%, much lower than that of their counterparts (31.7%).

For the other covariates, the participation rates of school based or non-school based exercise are lower for students whose school is within their community (83.7% and 28.0%, respectively), compared to those of students whose school is outside their community (88.3% and 35.8%, respectively). Similarly, the average intensity spent on total physical activity per student per week is 13.5 METs, significantly lower than that of their counterparts at 17.3 METs.

Table 2. Summary Statistics of Study Population by Availability of School Within Community

	Total (N=3,932)	
	School outside community (N=1,694)	**School within community (N=2,238)**
Outcomes		
Overweight (%)	6.26	8.94**
Obese (%)	1.30	3.13**
BMI z-score	-0.53	-0.53
AST		
% AST time per day (%)	1.25	1.03**
Duration of AST time per day (min)	18.00	14.83
Walking or cycling (actively commuting) to school (%) †	88.11	94.98**
Walking to school (%) †	57.56	84.62**
Cycling to school (%) †	31.66	8.89**
PA		
Participation in PA in school (%) †	88.33	83.67**
Participation in PA outside school (%) †	35.80	28.02**
Activity intensity from total PA in or outside school (METS)	17.32	13.52**
Community Urbanization Indices		
Total Urbanization Score	58.67	56.93**
Transportation component score	5.51	5.59
Market component score	5.18	5.55*
Modern markets component score	3.98	4.63**
Communication component score	5.36	5.21**
Housing component score	6.37	5.75**
Sanitation score	6.06	5.45**
Community population density score	5.71	5.50**
Quality of health score	5.38	5.25
Diversity score	4.68	4.41**
Social services score	2.10	1.81*
Community education score	3.20	3.05**
Economic component score	5.12	4.73**
Nutrition		
Calorie intake per day (kcal)	1,946	1780**
Household characteristics		
Family size	4.15	4.33**
Mother' BMI	22.99	22.51**
Individual characteristics		
Urban residence (%)	26.74	23.99
Boys (%)	53.96	51.88
Age at the baseline	9.51	8.66**

* $p<0.05$ ** $p<0.01$; $\chi 2$ test was used to determine the differences in the proportion of categorical variables across survey years; ANOVA analysis for test of statistical difference of continuous variables.

† Variables not used in regression analysis: number of observations in the sample of this study with complete information of variable-actively commuting to school is 3,801, of variable-walking to school is 3,896, of variable-cycling to school is 3,842, of variable-PA in school is 3,903, of variable-PA outside school 3,889.

A larger urbanization score reflected a high level of urbanization for a community. The total urbanization score was lower for communities that have a school than for those without a school (56.9 vs. 58.7); the trend continued for some components of the urbanization index including: communication (5.2 vs. 5.4), housing (5.8 vs. 6.4), sanitation (5.5 vs. 6.1), population density (5.5 vs. 5.7), health quality (5.3 vs. 5.4), diversity (4.4 vs. 4.7), social services (1.8 vs. 2.1), education (3.1 vs. 3.2), and economy (4.7 vs. 5.1). On the contrary, communities that have a school have higher scores in three components of the urbanization index than those that did not have a school, including: transportation (5.6 vs. 5.5), market (5.6 vs. 5.2), and modern markets (4.6 vs. 4.0). In addition, calorie intake per day (1,780 vs. 1,946) and mother's BMI (22.5 vs. 23.0) are lower for students whose school is within their community compared to those whose school is outside their community. In the sample, 24.0% of students living in communities with a school are from urban areas with an average age of nine years old at the baseline survey, while 26.7% of their counterparts are urban residents with an average age of ten years at baseline. No significant gender difference has been found between these two groups.

Trend Analysis

The proportion of active commuters across the five survey years is displayed in Figure 2. The proportion of students who actively commute to school deceased from 98% in 1997 to 81% in 2009 (Mantel–Haenszel test for trend $p<0.001$). Figure 3 describes the trends of the proportion of active commuters by the availability of a school within the community. It also shows a stable decrease in the proportion of active commuters in both groups, with less decrease among students whose school is within their community. The curve remains high for this group (Mantel–Haenszel test for trend $p<0.001$).

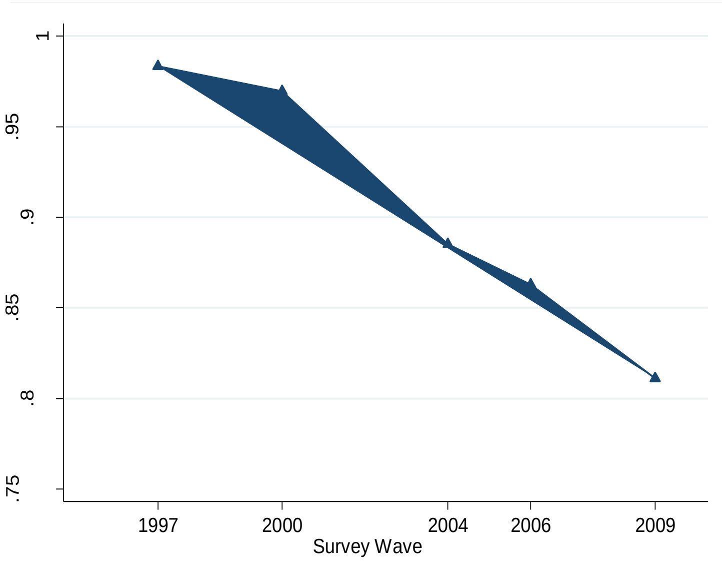

Figure 2. Average proportion of active commuters across five survey waves

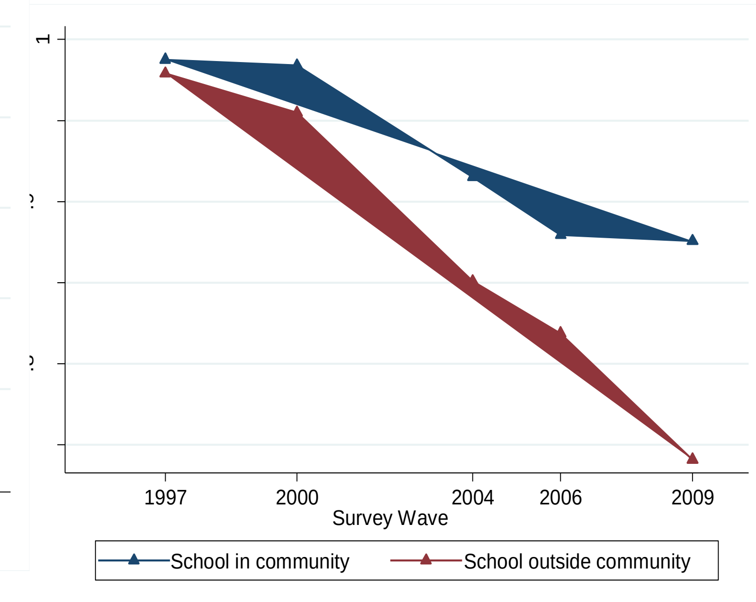

Figure 3. Average proportion of active commuters across waves by availability of school within community

Figure 4 shows that the average % AST time across the five survey waves among all students in the sample is fairly stable and in the range of 1.09% - 1.21%. Concurrently, the average % AST time among students whose school is within the community remains lower than that of their counterparts and continues on a downward trend from 2000 to 2009, which is displayed in Figure 5.

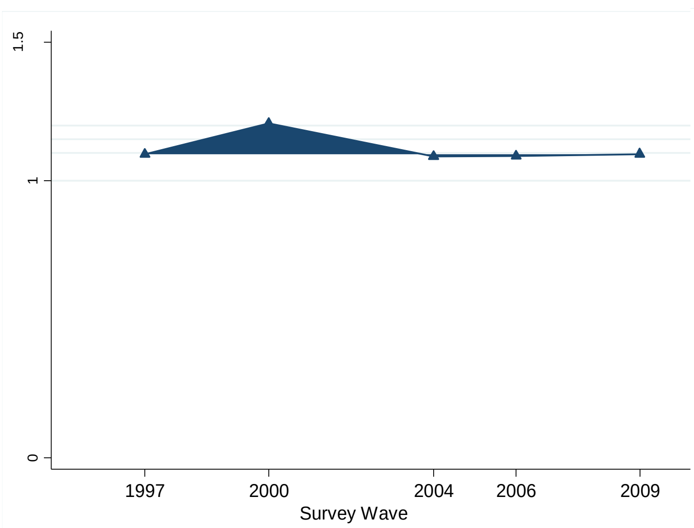

Figure 4. Average % AST time across five survey waves

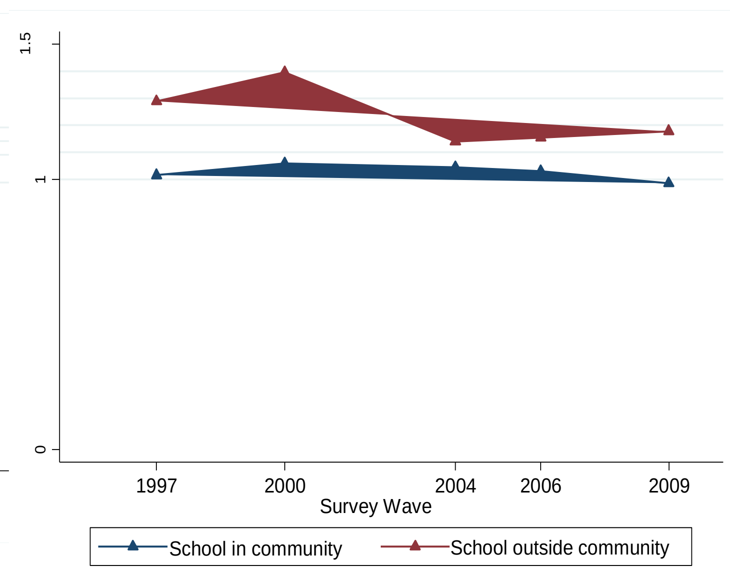

Figure 5. Average % AST time across waves by availability of school within community

Figure 6 summarizes the increasing trend in the proportion of overweight and obese students among all students across the five waves. Overall, the proportion of overweight students increased from 6.5 % in 1997 to 10.7% in 2009 (Mantel–Haenszel test for trend p=0.0007), and the proportion of obese students increased from 2.5% in 1997 to 3.3% in 2009 (Mantel–Haenszel test for trend p=0.23). Figure 7 divides the trend shown in Figure 6 by the availability of school within community, and it illustrates that the general trends of overweight and obesity increase for both groups.

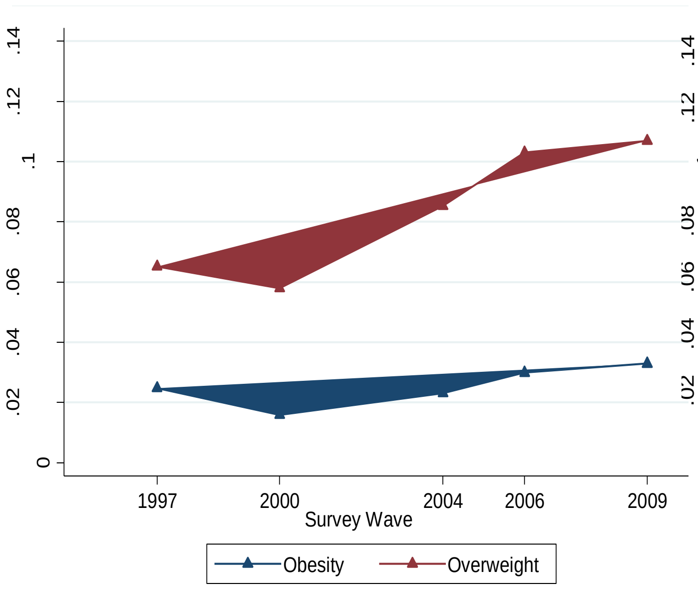

Figure 7. Average proportion of obese/overweight students across five survey waves

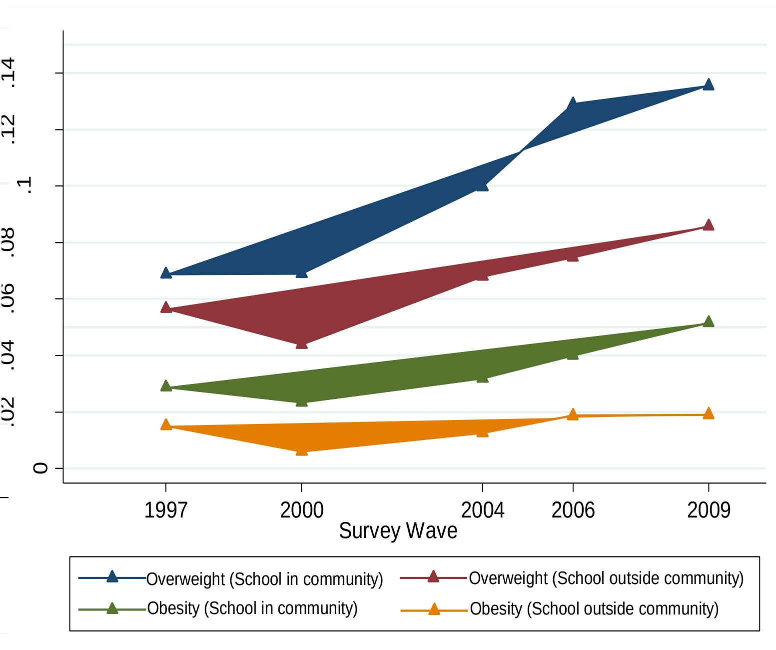

Figure 6. Average proportion of obese/overweight students across waves by availability of school within community

Specifically, the trends for overweight and obesity in students whose school is within their community increases from 7% in 1997 to 14% 2009 (Mantel–Haenszel test for trend p=0.0013), and from 3% 1997 to 5% in 2009 (Mantel–Haenszel test for trend p=0.35), respectively. Simultaneously, the trend for overweight and obesity generally increase from 6% in 1997 to 9% in 2009 (Mantel–Haenszel test for trend p=0.19), and from 1.5% 1997 to 1.9% in 2009 (Mantel–Haenszel test for trend p=0.49), respectively in students whose school is outside their community, and the curves remain lower than curves of their counterparts across the five waves.

Generally, I found an increasing trend in childhood overweight status and obesity, and a decreasing trend in active school commuting modes among Chinese students. Our findings, based on the trend analysis across the five survey years, are consistent with conclusions from previous studies.

Regression Analysis

% AST Time and Being Overweight

In the first models, a dichotomous outcome of whether the child was overweight was used as the outcome variable. In these first two models I considered only the isolated effects of % AST time and school location. After controlling for potential confounders in both random (Table 3 Column 1) and fixed effects (Table 3 Column2) models, I found a negative effect of % AST time on the probability of being overweight. However, this effect was only statistically significant in the model with random effects methods and became insignificant in the model with fixed effects methods. Hausman tests indicated the fixed effects models were preferred.

In the next two models, I re-estimated the above models; and only in these models, I included the interaction term – % AST time*availability of school within community. The results revealed that a 1% increase in AST time among those whose school was in their community reduced the probability of being overweight by 2.8% when estimated in random effects model (Table 3 Column 3) and by 2.7% when estimated using person fixed effects (Table 3 Column 4). For reference, a 1% increase in AST time amounts to about an additional 15 minutes per day in commute time.

As expected based on the summary in Table 2, there was a positive main effect of the availability of school within community, suggesting that students who have access to school within their community may be more likely to be overweight compared to their counterparts. This is also consistent with the result from trend analysis. As expected, there was a negative effect of the intensity of total exercise time on being overweight, yet the effect is only significant in random effects models. Generally, the effects of urbanization measures were not significant. The economic component of the urbanization index is the only one whose effect is significant and positive in all four models, suggesting that the residents are more likely to become overweight if their community has a better local economy. No significant or consistent effect on overweight was found from other explanatory variables in the four models including: calorie intake, family size, and parental BMI. Age at baseline and gender are excluded in fixed effects models because these variables are time invariant.

% AST Time and Being Obese

Similar results were detected when using being obese as the outcome. Specifically, when considering only the isolated effects of % AST time and school location, I found a significant effect of AST time on being obese in the random effects model (Table 4 Column 1); however, the effect became insignificant in the model using fixed effects methods (Table 4 Column 2).

In the next two models, I re-estimated the above models; and only in these two models, I added an interaction term -- % AST time*being obese. The results suggested that a 1 % increase in AST time among students whose school was within community decreased the probability of being obese by 1.5% when estimated in random effects models (Table 4 Column 3) and by 1.8% when using person fixed effects (Table 4 Column 4). Based on Hausman tests, the fixed effects models were preferred.

Concurrent with the summary in Table 2, there was a positive effect of the availability of school within community and, as expected, a negative effect of the intensity of total exercise time on being obese. Additionally, a higher score of the economic component of the urbanization index increased the probability of being obese. The effect, however, was only significant in random effects models.

% AST Time and BMI z-score

I also used BMI z-score as the outcome. The effect of % AST time on BMI z-score is significant in neither random effects nor fixed effects models (Table 5 Column 1-2), when considering only the isolated effects of % AST time and school location.

In the next two models, I included the interaction term – BMI z-score*availability of school within community. The results showed that among students who had access to school in their local community, an increase in AST time decreased BMI z-score when estimated in models using random effects (Table 5 Column 5); but the effect became insignificant when using person fixed effects (Table 5 Column 4).

For the other covariates, the results revealed a positive effect of availability of school within community, a negative effect of intensity of total exercise time, a positive effect of mom's BMI, and a positive effect of the density component of urbanization indices on BMI z-score in random effects models; however, all these effects became statistically insignificant when using person fixed effects methods.

In conclusion, the effect of AST time on childhood obesity or overweight was found statistically insignificant among all students in the sample, while among students who had access to school within their communities, an increase in AST time decreased the probability of becoming overweight or obese. Increasing AST time, however, cannot significantly decrease BMI z-score among these students.

Table 3. Effect of % AST time on probability of being overweight

	Model 1	Model 2	Model 3	Model 4
	RE	**FE**	**RE with Interaction**	**FE with Interaction**
% AST time	-0.0101**	-0.00186	0.00315	0.0109
	[0.004]	[0.006]	[0.005]	[0.007]
Access to school within community	0.0247**	0.0124	0.0562***	0.0424+
	[0.008]	[0.014]	[0.013]	[0.022]
% AST time * Access to school within community			-0.0280***	-0.0269*
			[0.008]	[0.012]
Intensity from PA in or outside school	-.000647**	-0.000529	-.000677**	-0.000567
	[0.000]	[0.000]	[0.000]	[0.000]
Urbanization Index: Communication component score	0.00677+	0.000780	0.00681+	0.000900
	[0.004]	[0.007]	[0.004]	[0.007]
Urbanization Index: Community population density	0.00287	-0.0179	0.00296	-0.0179
	[0.004]	[0.019]	[0.004]	[0.019]
Urbanization Index: Diversity score	0.00299	-0.00837	0.00264	-0.00848
	[0.007]	[0.011]	[0.007]	[0.011]
Urbanization Index: Economic component score	0.00820***	0.00890**	0.00818***	0.00880**
	[0.002]	[0.003]	[0.002]	[0.003]
Urbanization Index: Quality of health score	0.00226	-0.00142	0.00206	-0.00164
	[0.002]	[0.004]	[0.002]	[0.004]
Urbanization Index: Housing component score	-0.00324	0.00103	-0.00301	0.00102
	[0.004]	[0.008]	[0.004]	[0.008]
Urbanization Index: Market component score	-0.00128	-0.000275	-0.00130	-0.000383
	[0.001]	[0.002]	[0.001]	[0.002]
Urbanization Index: Social services score	-0.00134	-0.00242	-0.00160	-0.00276
	[0.003]	[0.004]	[0.003]	[0.004]
Urbanization Index: Transportation component score	0.00148	0.00000733	0.00152	-.00000666
	[0.002]	[0.004]	[0.002]	[0.004]
Urbanization Index: Community education category	-0.00210	-0.0507+	-0.00203	-0.0511*
	[0.006]	[0.026]	[0.006]	[0.026]
Urbanization Index: Modern markets component score	0.000305	0.00257	0.000585	0.00299
	[0.002]	[0.003]	[0.002]	[0.003]
Urbanization Index: Sanitation score	0.00121	-0.00333	0.00138	-0.00282
	[0.002]	[0.005]	[0.002]	[0.005]
Calorie intake per day (kcal)	0.00000174	0.00000547	0.00000138	0.00000484
	[0.000]	[0.000]	[0.000]	[0.000]
Mom's BMI	0.00934***	-0.00226	0.00935***	-0.00221
	[0.002]	[0.005]	[0.002]	[0.005]
Family size	-0.00245	0.0273+	-0.00250	0.0271+
	[0.005]	[0.014]	[0.005]	[0.014]
Age at baseline	-0.0458*	.	-0.0428*	.
	[0.022]	.	[0.022]	.
Squared age at baseline wave	0.00182+	.	0.00167	.
	[0.001]	.	[0.001]	.
Male	0.0452***	.	0.0451***	.
	[0.011]	.	[0.011]	.
Year 2000	-0.00373	0.0148	-0.00328	0.0158
	[0.010]	[0.017]	[0.010]	[0.017]
Year 2004	-0.00379	0.0135	-0.00223	0.0154
	[0.015]	[0.026]	[0.015]	[0.026]
Year 2006	-0.00267	0.00968	-0.00141	0.0111
	[0.018]	[0.033]	[0.018]	[0.033]
Year 2009	-0.0201	-0.0167	-0.0185	-0.0145
	[0.022]	[0.044]	[0.022]	[0.044]
Constant	0.0211	0.262	-0.0104	0.246
	[0.114]	[0.205]	[0.114]	[0.204]
Observations	3932	3932	3932	3932

Standard errors in brackets, + *p*< 0.10, * *p*< 0.05, ** *p*< 0.01, *** *p*< 0.001

Table 4. Effect of % AST time on probability of being obese

	Model 1	Model 2	Model 3	Model 4
	RE	FE	RE with Interaction	FE with Interaction
% AST time	-0.00458*	-0.00336	0.00231	0.00516
	[0.002]	[0.003]	[0.003]	[0.005]
Access to school within community	0.0142**	0.00412	0.0305***	0.0241+
	[0.005]	[0.007]	[0.008]	[0.013]
% AST time * Access to school within community			-0.0145**	-0.0179*
			[0.005]	[0.008]
Intensity from PA in or outside school	-0.000142	-0.000128	-0.000158	-0.000153
	[0.000]	[0.000]	[0.000]	[0.000]
Urbanization Index: Communication component score	0.00275	0.00192	0.00277	0.00200
	[0.002]	[0.004]	[0.002]	[0.004]
Urbanization Index: Community population density	0.00194	-0.00513	0.00198	-0.00514
	[0.002]	[0.010]	[0.002]	[0.009]
Urbanization Index: Diversity score	-0.00319	0.00242	-0.00335	0.00235
	[0.004]	[0.007]	[0.004]	[0.007]
Urbanization Index: Economic component score	0.00222*	0.00269	0.00221*	0.00262
	[0.001]	[0.002]	[0.001]	[0.002]
Urbanization Index: Quality of health score	0.000629	-0.00192	0.000525	-0.00207
	[0.001]	[0.002]	[0.001]	[0.002]
Urbanization Index: Housing component score	0.000574	0.00694	0.000708	0.00693
	[0.002]	[0.004]	[0.002]	[0.004]
Urbanization Index: Market component score	-0.000449	0.00125	-0.000456	0.00117
	[0.001]	[0.001]	[0.001]	[0.001]
Urbanization Index: Social services score	-0.00133	-0.00398	-0.00147	-0.00420
	[0.002]	[0.003]	[0.002]	[0.003]
Urbanization Index: Transportation component score	-0.000110	-0.000837	-0.0000878	-0.000846
	[0.001]	[0.002]	[0.001]	[0.002]
Urbanization Index: Community education category	0.000475	-0.0221	0.000500	-0.0224
	[0.004]	[0.015]	[0.004]	[0.015]
Urbanization Index: Modern markets component score	-0.00104	-0.000878	-0.000900	-0.000597
	[0.001]	[0.002]	[0.001]	[0.002]
Urbanization Index: Sanitation score	0.000502	-0.00222	0.000580	-0.00188
	[0.001]	[0.003]	[0.001]	[0.003]
Calorie intake per day (kcal)	-.00000576	0.000000979	-.00000593	.000000564
	[0.000]	[0.000]	[0.000]	[0.000]
Mom's BMI	0.000930	-0.00558+	0.000933	-0.00554+
	[0.001]	[0.003]	[0.001]	[0.003]
Family size	0.000130	0.0126	0.000109	0.0125
	[0.003]	[0.009]	[0.003]	[0.009]
Age at baseline	-0.0274*	.	-0.0258*	.
	[0.013]	.	[0.013]	.
Squared age at baseline wave	0.00118+	.	0.00110+	.
	[0.001]	.	[0.001]	.
Male	0.0140*	.	0.0139*	.
	[0.006]	.	[0.006]	.
Year 2000	-0.00309	0.000892	-0.00288	0.00157
	[0.007]	[0.010]	[0.007]	[0.010]
Year 2004	-0.00822	-0.0150	-0.00744	-0.0137
	[0.008]	[0.013]	[0.009]	[0.013]
Year 2006	-0.00902	-0.0292+	-0.00842	-0.0282
	[0.010]	[0.017]	[0.010]	[0.017]
Year 2009	-0.0124	-0.0423+	-0.0117	-0.0408+
	[0.013]	[0.024]	[0.013]	[0.024]
Constant	0.133*	0.164	0.117+	0.153
	[0.064]	[0.126]	[0.065]	[0.126]
Observations	3932	3932	3932	3932

Standard errors in brackets
+ *p*< 0.10, * *p*< 0.05, ** *p*< 0.01, *** *p*< 0.001

Table 5. Effect of % AST time on BMI z-score

	Model 1	Model 2	Model 3	Model 4
	RE	**FE**	**RE with Interaction**	**FE with Interaction**
% AST time	-0.0221	0.0199	0.0234	0.0530+
	[0.016]	[0.024]	[0.021]	[0.032]
Access to school within community	0.0322	0.0135	0.140**	0.0911
	[0.033]	[0.049]	[0.047]	[0.069]
% AST time*Access to school within community			-0.0960**	-0.0696
			[0.031]	[0.045]
Intensity from PA in or outside school	-0.00218*	-0.00108	-0.00229**	-0.00117
	[0.001]	[0.001]	[0.001]	[0.001]
Urbanization Index: Communication component score	0.0180	-0.00436	0.0182	-0.00405
	[0.015]	[0.024]	[0.015]	[0.024]
Urbanization Index: Community population density	0.00446	-0.0429	0.00478	-0.0430
	[0.016]	[0.059]	[0.016]	[0.059]
Urbanization Index: Diversity score	0.0656**	0.0329	0.0646**	0.0327
	[0.025]	[0.049]	[0.025]	[0.049]
Urbanization Index: Economic component score	0.00970	0.00359	0.00956	0.00333
	[0.007]	[0.012]	[0.007]	[0.012]
Urbanization Index: Quality of health score	0.00250	-0.00855	0.00182	-0.00913
	[0.009]	[0.013]	[0.009]	[0.013]
Urbanization Index: Housing component score	-0.00933	0.0168	-0.00875	0.0167
	[0.014]	[0.030]	[0.014]	[0.030]
Urbanization Index: Market component score	-0.00683	-0.000122	-0.00698	-0.000402
	[0.005]	[0.008]	[0.005]	[0.008]
Urbanization Index: Social services score	-0.00957	-0.0161	-0.0105	-0.0170
	[0.009]	[0.013]	[0.009]	[0.013]
Urbanization Index: Transportation component score	-0.00288	-0.00377	-0.00277	-0.00381
	[0.008]	[0.013]	[0.008]	[0.013]
Urbanization Index: Community education category	0.0319	-0.0344	0.0321	-0.0355
	[0.023]	[0.089]	[0.023]	[0.089]
Urbanization Index: Modern markets component score	-0.000275	0.00924	0.000794	0.0103
	[0.007]	[0.012]	[0.007]	[0.012]
Urbanization Index: Sanitation score	0.0146	-0.0139	0.0154	-0.0126
	[0.010]	[0.020]	[0.010]	[0.020]
Calorie intake per day(kcal)	0.0000258	0.0000214	0.0000244	0.0000198
	[0.000]	[0.000]	[0.000]	[0.000]
Mom's BMI	0.0725***	0.0372+	0.0726***	0.0374+
	[0.007]	[0.020]	[0.007]	[0.019]
Family size	-0.0423*	0.0636	-0.0426*	0.0632
	[0.019]	[0.048]	[0.019]	[0.047]
Age at baseline	-0.141	.	-0.130	.
	[0.090]	.	[0.090]	.
Squared age at baseline wave	0.00474	.	0.00422	.
	[0.004]	.	[0.005]	.
Male	0.111*	.	0.111*	.
	[0.045]	.	[0.045]	.
Year 2000	-0.0468	-0.0198	-0.0448	-0.0172
	[0.042]	[0.068]	[0.042]	[0.067]
Year 2004	-0.0650	-0.0321	-0.0591	-0.0271
	[0.058]	[0.104]	[0.058]	[0.103]
Year 2006	-0.0981	-0.0796	-0.0934	-0.0759
	[0.066]	[0.130]	[0.066]	[0.130]
Year 2009	-0.155+	-0.148	-0.148+	-0.142
	[0.083]	[0.166]	[0.083]	[0.166]
Constant	-1.673***	-1.421*	-1.782***	-1.463*
	[0.489]	[0.705]	[0.491]	[0.701]
Observations	3932	3932	3932	3932

Standard errors in brackets, + *p*< 0.10, * *p*< 0.05, ** *p*< 0.01, *** *p*< 0.001

5. Discussion

Commuting Modes and Childhood Obesity

The data in the CNHS suggest Chinese students actively commuting to school decreased by almost 20 percent from 1997 to 2009. During the same decade, the proportion of obese or overweight Chinese students doubled. These coincident trends raise concerns about the increase of childhood obesity and lack of physical activity among students in China.

The principle aim of this study is to determine the association between actively commuting to and from school and childhood obesity in Chinese school children and adolescents. After controlling for potential confounders and including individual fixed effects, active commuting shows an insignificant independent effect on obesity (overweight) status among all students in our sample. There is a significant, negative interaction effect of % AST time and school location on obesity. This suggests that among students whose schools are available within their community (village), these students are less likely to become obese or overweight, as long as they spend more time actively commuting to and from school. The negative effect of active transportation modes on childhood obesity is greater for students whose schools are within their community compared to those whose schools are outside their community. Furthermore, students who have schools within their community may be more likely to have a walkable or bikeable distance between home and school. Thus, our results indicate that active commuting does not sufficiently affect body weight among all Chinese students, and that the availability of a walkable or bikeable distance between home and school has to be taken into account.

I also found evidence that students whose school is within their community are more likely to become obese or overweight compared to those whose school is outside community (Figure 6 and the estimates in Table 3-4). Interestingly, transportation scores in the urbanization index, of which higher scores indicate better public transportation infrastructure, were positively related to students attending a school located in their community. In contrast to AST, public transport potentially reduces opportunities for active commuting, and decreases the total amount of daily exercises for students living in these communities. In addition, better local infrastructure is generally associated with better economic circumstances for families in China. Thus the interaction effect between % AST and school location is likely indicative of AST mitigating some of the effects of affluence on obesity.

Additionally, students whose schools are within their community have a higher frequency of walking but a lower frequency of cycling. Although these students walk frequently, since they live closer to school, the intensity of physical activity involved may be minimal and less efficient in countering obesity [69] as a result of “strolling” for the walking distance to school [50]. Similarly, among these students, the proportion of daily active commuting time on average was found to be lower. This result also indicates less intensity from AST.

Furthermore, communities with schools and better public infrastructures have been theorized to be more urban, and where children are better fed, or even overfed, and mostly come from families that own a car and engage in less exercise. Due to these compounded factors, children from these communities are more likely to be obese. However, while I did find better transportation scores, I did not find an overall significantly higher urbanization index for these communities compared to others in this study. Thus, general urbanization as an explanation does not suffice.

Few studies have taken into account commuting distance when examining the effect of active commuting on body weight in children. Heelan et al. developed an index to describe active commuting to and from school consisting of commuting distance and frequency of active commuting in U.S. children aged 9 to 11 [35]. They found a positive correlation between this index and BMI. These unexpected findings may be explained by a high proportion of overweight children and the age of the sample. Unlike the Heelan et al. study, Landsberg et al. found a significantly negative association between the interaction term “active commuting by distance to school” and FM, suggesting that, in actively commuting adolescents, FM decreased with increasing distance between home and school [49]. Compared to these U.S. studies, my study focuses on a student population in China, and uses a different measure as a proxy of distance between home and school, which may limit the comparability between this and previous U.S. studies. In addition, inconsistent with some studies conducted in Western countries [49], this study does not find any significant differences in the effect of AST on obesity when stratified our student sample by gender, age (younger children vs. adolescents), or residence (urban vs. rural). Furthermore, some studies reported a higher level of total physical activity among active commuters [49]. Consistent with this finding, our study found that active commuting time can significantly and positively predict the total physical activity time of a student on average. This may be explained because active school commuters are more likely to remain stimulated to be physically active throughout the day as a result of walking or cycling to and from school [37].

Study Strength and Limitations

The study has two main contributions. First, this study focuses on Chinese school children and adolescents, and provides one of the first observations of data linking active commuting plus the location of school and indicators of childhood obesity among this population. Second, this study adds evidence to the few existing longitudinal studies to explore the association between active school transportation and childhood/adolescent obesity. In addition, the model specifications may be problematic if only using random fixed effect methods because the random effects model assumes that the errors are orthogonal to all explanatory variables. If this is not the case, the estimated coefficients may be biased, even though the standard errors are smaller [64]. However, by adding individual and time two-way fixed effects models, I found consistent results. Using both fixed and random effect methods reduces bias and improves the consistency of our estimation, conclusions related to causality.

This study also has some limitations. First, data in this study were collected based on self-reporting, and parents necessarily assisted younger children (<10 years of age) with the survey; therefore, reporting bias cannot be ruled out. There may be overestimation or underestimation of active commuting activity due to an inability to obtain an objective measure of the actual use of transportation modes. However, proxy reports are practical approaches for large study populations and permit researchers to avoid recall biases associated with the cognitive limitations of young children [70]. Second, the sample size of this study is not nationally representative. The nine sampling provinces of CHNS are mainly located in eastern and northern coastal regions of China, which have a higher socioeconomic status compared to other regions in China. However, this may not be an insurmountable obstacle for this study because the CHNS student sample captures the majority of the obese or overweight student population in China who are most likely to come from these sampling regions with a higher income and living standard. Third, there is no direct measure of distance between home and school; and the access to students' schools within communities is a proxy of the distance. This may limit the conclusion on how the relationship between AST and obesity is modified by changes in distance between home and school. This may also limit the comparability between our results and previous studies. Fourth, even after adjustment, as in most existing studies, a substantial amount of BMI variances still remained in the multivariable models. For instance, while I controlled for the Mother's BMI in regression models, it is impossible to control all aspects related to household preferences. However, this study utilizes individual fixed and random effects methods to adjust for characteristics that do not vary across time, such as time invariant individual and household preferences, as well as genetic factors uninfluenced by environments. Thus, the incomplete adjustment has been relieved by random and fixed effects methods. Furthermore, there were some changes in survey questions related to AST and other physical activities in CHNS questionnaires in 1997, 2000, and 2004. However, based on sensitive analyses using sub data sets in 2000-2009 and 2004-2009, I noted consistent results (results from sensitive analyses have not been reported here), which confirmed that the questionnaire changes would not lead to systematic bias of this study.

Policy Implications

Despite the proven benefit of being physical active throughout the day, the educational system in China hampers students' abilities to do so. Providing a good education is especially valued in Chinese society [71]. Youth in China are under great pressure to perform well in school, and heavy homework loads are typical [72]. A university education is seen as the only path to a quality career, and the pressure to succeed scholastically begins early since university entrance is restricted [72]. Therefore, parents' high expectations for their children to excel academically in concert with the current education curriculum in China have increased sedentary lifestyles and decreased students' physical activity time, due to excessive study time. These expectations have been deeply ingrained in Chinese culture and will not be soon relieved. Additionally, the Chinese diet is becoming more westernized with the inclusion of high fat and carbohydrate rich foods. This is especially true in the coastal regions in China where our data were collected. As a result, there is a growing proportion of pediatric and adolescent overweight and obesity in China, and any opportunity to increase children's and adolescents' physical activity should be supported.

Incorporating more physical activity into daily life, for example through increasing active commuting time on the journey to school, is an important source of daily exercise and long-term maintenance of initial increases in physical activity [73, 74]. It has previously been suggested that frequent walking and cycling, regardless of intensity and destination, expends energy and is therefore important to prevent overweight [47]. Based on our main findings, while increasing AST may be an appropriate focus to reduce obesity among some school children in China, it is unlikely to impact everyone and will be most successful on childhood obesity prevention among children whose school is within their local community. Thus, interventions aimed at reducing childhood obesity among Chinese students should refocus on the promotion of daily active commuting time, and specifically target students whose school is located within their community. As there is a lower proportion of cyclists among students whose schools are located within their community, interventions should also include the promotion of sustained cycling and brisk walking en route to school, which is a more intensive exercise compared to strolling. Furthermore, our findings also suggest that AST only is insufficient to address the overall childhood obesity problem in China. Future interventions other than AST may be necessary for students travelling outside of their immediate communities for education.

Barriers for Active Commuting and Future Direction

Above all, future research should include objective measures to determine the relationship of active commuting to school, energy balance, and thus its influence on body weight. These measures are physical activity, energy intake, and energy expenditure. In addition, future studies should also consider large, nationally representative samples, and follow up surveys, as well as objective and direct measurement of distance between home and school as the key mediator. These help to determine the unbiased effect of active commuting on current and future indicators of obesity and other health outcomes among Chinese students.

There has been a call to develop and implement interventions to increase active commuting [91], and parents' awareness of their children's physical and social environment. However, the resources available to families during typically chaotic school mornings, as well as parents' perception of their child's personal ability to manage such a trip safely, may influence commuting modes to school for children and adolescents [75]. In an Australian study [76], major barriers to active commuting have been attributed to parents' reporting of fewer other children living within their neighborhood, lack of street lighting or pedestrian crossings, and objective measurements of increased road traffic [12]. However, few studies in China link potential barriers to active school commuting. Considering the decreasing prevalence of students who actively commute to school across the decade under this study, future studies may need to consider exploring the perceived barriers for active commuting in China, using mixed methods. Local governments in China should also incorporate such considerations into infrastructural changes, town and city planning, land-use development decisions, and provision of services.

6. Conclusion

This study provides new evidence that increasing AST time is not likely to impact every Chinese student equally, and will be most likely to successfully reduce obesity among students whose school is located within their community. Therefore, when contemplating the implementation of AST policies or interventions, it is critical to consider the location of the target school.

In the context of often excessive study time demands and decreasing physical activity time for Chinese students, any opportunity to increase their physical activity, such as AST, should be supported. However, interventions other than AST may be necessary for students travelling outside of their immediate communities for education. Our findings suggest that AST has value for many students, but is likely insufficient to address the overall childhood obesity problem in China.

References

[1] Aires, L., et al., *A 3 year longitudinal analysis of changes in body mass index.* Levels of Physical Activity, Physical Fitness and Overweight/Obesity in Children and Adolescents, 2010: p. 105.

[2] Popkin, B.M. and C.M. Doak, *The obesity epidemic is a worldwide phenomenon.* Nutrition reviews, 2009. **56**(4): p. 106-114.

[3] Robinson, T.N. and J.R. Sirard, *Preventing childhood obesity: a solution-oriented research paradigm.* American Journal of Preventive Medicine, 2005. **28**(2): p. 194-201.

[4] Wang, Y. and T. Lobstein, *Worldwide trends in childhood overweight and obesity.* International Journal of Pediatric Obesity, 2006. **1**(1): p. 11-25.

[5] Allison, D.B., et al., *Annual deaths attributable to obesity in the United States.* JAMA: the journal of the American Medical Association, 1999. **282**(16): p. 1530-1538.

[6] Singh, A.S., et al., *Tracking of childhood overweight into adulthood: a systematic review of the literature.* Obesity Reviews, 2008. **9**(5): p. 474-488.

[7] Wabitsch, M., *Overweight and obesity in European children: definition and diagnostic procedures, risk factors and consequences for later health outcome.* European journal of pediatrics, 2000. **159**(13): p. 8-13.

[8] Gomez, L., et al., *Television viewing and its association with overweight in Colombian children: results from the 2005 National Nutrition Survey: A cross sectional study.* International Journal of Behavioral Nutrition and Physical Activity, 2007. **4**(1): p. 41.

[9] Bell, A.C., K. Ge, and B.M. Popkin, *The road to obesity or the path to prevention: motorized transportation and obesity in China.* Obesity Research, 2012. **10**(4): p. 277-283.

[10] Frank, L.D., M.A. Andresen, and T.L. Schmid, *Obesity relationships with community design, physical activity, and time spent in cars.* American Journal of Preventive Medicine, 2004. **27**(2): p. 87-96.

[11] Wen, L., et al., *Driving to work and overweight and obesity: findings from the 2003 New South Wales Health Survey, Australia.* International Journal of Obesity, 2006. **30**(5): p. 782-786.

[12] Dollman, J., K. Norton, and L. Norton, *Evidence for secular trends in children's physical activity behaviour.* British Journal of Sports Medicine, 2005. **39**(12): p. 892-897.

[13] Must, A. and D. Tybor, *Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth.* International Journal of Obesity, 2005. **29**: p. S84-S96.

[14] Robinson, T.N., *Television viewing and childhood obesity.* Pediatric Clinics of North America, 2001. **48**(4): p. 1017-1025.

[15] Mokdad, A.H., et al., *The spread of the obesity epidemic in the United States, 1991-1998.* JAMA: the journal of the American Medical Association, 1999. **282**(16): p. 1519-1522.

[16] Flegal, K.M. and R.P. Troiano, *Changes in the distribution of body mass index of adults and children in the US population.* International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity, 2000. **24**(7): p. 807.

[17] Colditz, G.A., *Economic costs of obesity and inactivity.* Medicine and science in sports and exercise, 1999. **31**(11 Suppl): p. S663.

[18] Andersen, L.B., et al., *Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study).* The Lancet, 2006. **368**(9532): p. 299-304.

[19] Wedderkopp, N., et al., *Secular trends in physical fitness and obesity in Danish 9 ‐ year ‐ old girls and boys: Odense School Child Study and Danish substudy of the European Youth Heart Study.* Scandinavian journal of medicine & science in sports, 2004. **14**(3): p. 150-155.

[20] Pate, R.R., et al., *Tracking of physical activity in young children.* Medicine and science in sports and exercise, 1996. **28**(1): p. 92.
[21] Telama, R., et al., *Physical activity in childhood and adolescence as predictor of physical activity in young adulthood.* American Journal of Preventive Medicine, 1997.
[22] Taylor, W.C., et al., *Childhood and adolescent physical activity patterns and adult physical activity.* Medicine and science in sports and exercise, 1999. **31**(1): p. 118.
[23] Prentice, A.M., *The emerging epidemic of obesity in developing countries.* International Journal of Epidemiology, 2006. **35**(1): p. 93-99.
[24] Bell, A., K. Ge, and B. Popkin, *Weight gain and its predictors in Chinese adults.* International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity, 2001. **25**(7): p. 1079.
[25] Paeratakul, S., et al., *Changes in diet and physical activity affect the body mass index of Chinese adults.* International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity, 1998. **22**(5): p. 424.
[26] Cui, Z., et al., *Temporal trends in overweight and obesity of children and adolescents from nine Provinces in China from 1991–2006.* International Journal of Pediatric Obesity, 2010. **5**(5): p. 365-374.
[27] Ji, C.Y., *The prevalence of childhood overweight/obesity and the epidemic changes in 1985－2000 for Chinese school－age children and adolescents.* Obesity Reviews, 2008. **9**: p. 78-81.
[28] Kim, S., M. Symons, and B.M. Popkin, *Contrasting socioeconomic profiles related to healthier lifestyles in China and the United States.* American journal of epidemiology, 2004. **159**(2): p. 184-191.
[29] Wang, Y., *Cross-national comparison of childhood obesity: the epidemic and the relationship between obesity and socioeconomic status.* International Journal of Epidemiology, 2001. **30**(5): p. 1129-1136.
[30] Wang, Y., C. Monteiro, and B.M. Popkin, *Trends of obesity and underweight in older children and adolescents in the United States, Brazil, China, and Russia.* The American journal of clinical nutrition, 2002. **75**(6): p. 971-977.
[31] Gordon-Larsen, P., et al., *Inequality in the built environment underlies key health disparities in physical activity and obesity.* Pediatrics, 2006. **117**(2): p. 417-424.
[32] Hu, G., et al., *Comparison of dietary and non-dietary risk factors in overweight and normal-weight Chinese adults.* British Journal of Nutrition, 2002. **88**(1): p. 91-97.
[33] Hu, G., et al., *Commuting, leisure-time physical activity, and cardiovascular risk factors in China.* Medicine and science in sports and exercise, 2002. **34**(2): p. 234.
[34] Cooper, A.R., et al., *Active travel to school and cardiovascular fitness in Danish children and adolescents.* Medicine and science in sports and exercise, 2006. **38**(10): p. 1724.
[35] Heelan, K.A., et al., *Active commuting to and from school and BMI in elementary school children–preliminary data.* Child: care, health and development, 2005. **31**(3): p. 341-349.
[36] Schofield, G., L. Schofield, and K. Mummery, *Active transportation-an important part of adolescent physical activity.* Youth Studies Australia, 2005. **24**(1): p. 43-47.
[37] Alexander, L.M., et al., *The broader impact of walking to school among adolescents: seven day accelerometry based study.* Bmj, 2005. **331**(7524): p. 1061-1062.
[38] Saksvig, B.I., et al., *Travel by walking before and after school and physical activity among adolescent girls.* Archives of pediatrics & adolescent medicine, 2007. **161**(2): p. 153.
[39] Qahwaji, D.M., *Commuting to School, Are Children Who Walk More Physically Active.* American Journal of Preventive Medicine, 2003. **25**(4).
[40] Sirard, J.R., et al., *Physical activity and active commuting to elementary school.* Medicine and science in sports and exercise, 2005. **37**(12): p. 2062.
[41] Davison, K.K., J.L. Werder, and C.T. Lawson, *Peer Reviewed: Children's Active Commuting to School: Current Knowledge and Future Directions.* Preventing chronic disease, 2008. **5**(3).

[42] Andersen, L.B., et al., *Physical fitness in relation to transport to school in adolescents: the Danish youth and sports study.* Scandinavian journal of medicine & science in sports, 2008. **19**(3): p. 406-411.
[43] Tudor-Locke, C., B.E. Ainsworth, and B.M. Popkin, *Active Commuting to School: An Overlooked Source of Childrens Physical Activity?* Sports Medicine, 2001. **31**(5): p. 309-313.
[44] infas and DIW. *Mobilita¨t in Deutschland: Ergebnisbericht*. 2004; Available from: http://www.kontiv2002.de/pdf/ergebnisbericht_mid_ende_144_punkte.pdf.
[45] Cui, Z., A. Bauman, and M.J. Dibley, *Temporal trends and correlates of passive commuting to and from school in children from 9 provinces in China.* Preventive medicine, 2011. **52**(6): p. 423-427.
[46] Bere, E., et al., *Socio-demographic factors as correlates of active commuting to school in Rotterdam, the Netherlands.* Preventive medicine, 2008. **47**(4): p. 412-416.
[47] Pabayo, R., et al., *Sustained active transportation is associated with a favorable body mass index trajectory across the early school years: findings from the Quebec Longitudinal Study of Child Development birth cohort.* Preventive medicine, 2010. **50**: p. S59-S64.
[48] Fulton, J.E., et al., *Active transportation to school: findings from a national survey.* Research quarterly for exercise and sport, 2005. **76**(3): p. 352-357.
[49] Landsberg, B., et al., *Associations between active commuting to school, fat mass and lifestyle factors in adolescents: the Kiel Obesity Prevention Study (KOPS).* European journal of clinical nutrition, 2007. **62**(6): p. 739-747.
[50] Madsen, K.A., et al., *Physical activity opportunities associated with fitness and weight status among adolescents in low-income communities.* Archives of pediatrics & adolescent medicine, 2009. **163**(11): p. 1014.
[51] Bourdeaudhuij, I., et al., *Physical activity and psychosocial correlates in normal weight and overweight 11 to 19 year olds.* Obesity research, 2012. **13**(6): p. 1097-1105.
[52] Klein-Platat, C., et al., *Physical activity is inversely related to waist circumference in 12-y-old French adolescents.* International journal of obesity, 2004. **29**(1): p. 9-14.
[53] Qin, L., R.P. Stolk, and E. Corpeleijn, *Motorized Transportation, Social Status, and Adiposity: The China Health and Nutrition Survey.* American Journal of Preventive Medicine, 2012. **43**(1): p. 1-10.
[54] Li, Y., et al., *Determinants of childhood overweight and obesity in China.* British Journal of Nutrition, 2007. **97**(01): p. 210-215.
[55] Lee, M.C., M.R. Orenstein, and M.J. Richardson, *Systematic review of active commuting to school and childrens physical activity and weight.* Journal of physical activity & health, 2008. **5**(6): p. 930.
[56] Bere, E. and L.B. Andersen, *Why no support for an association between active commuting to school and weight status in the literature.* J Phys Act Health, 2009. **6**(5): p. 533-4.
[57] Bere, E., et al., *The association between cycling to school and being overweight in Rotterdam (The Netherlands) and Kristiansand (Norway).* Scandinavian journal of medicine & science in sports, 2009. **21**(1): p. 48-53.
[58] Andersen, R.E., et al., *Relationship of physical activity and television watching with body weight and level of fatness among children.* JAMA: the journal of the American Medical Association, 1998. **279**(12): p. 938-942.
[59] Carolina Population Center. *China health and nutrition surveys: questionnaires/interviewer manual*. 2012; Available from: http://www.cpc.unc.edu/projects/china/data/questionnaires.
[60] Popkin, B.M., B. Lu, and F. Zhai, *Understanding the nutrition transition: measuring rapid dietary changes in transitional countries.* Public health nutrition, 2002. **5**(6A): p. 947-954.
[61] Zhai, F., et al., *Evaluation of the 24-hour individual recall method in China.* FOOD AND NUTRITION BULLETIN-UNITED NATIONS UNIVERSITY-, 1996. **17**: p. 154-161.

[62] Monda, K., et al., *Longitudinal relationships between occupational and domestic physical activity patterns and body weight in China.* European journal of clinical nutrition, 2007. **62**(11): p. 1318-1325.
[63] Zimmer, Z., T. Kaneda, and L. Spess, *An examination of urban versus rural mortality in China using community and individual data.* The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 2007. **62**(5): p. S349-S357.
[64] Ng, S.W., E.C. Norton, and B.M. Popkin, *Why have physical activity levels declined among Chinese adults? Findings from the 1991–2006 China health and nutrition surveys.* Social science & medicine, 2009. **68**(7): p. 1305-1314.
[65] Kleiser, C., et al., *Potential determinants of obesity among children and adolescents in Germany: results from the cross-sectional KiGGS study.* BMC Public Health, 2009. **9**(1): p. 46.
[66] McDade, T.W. and L.S. Adair, *Defining the "urban" in urbanization and health: a factor analysis approach.* Social science & medicine, 2001. **53**(1): p. 55-70.
[67] Karaca‐Mandic, P., E.C. Norton, and B. Dowd, *Interaction terms in nonlinear models.* Health services research, 2012. **47**(1pt1): p. 255-274.
[68] Wooldridge, J.M., *Introductory econometrics: a modern approach*2009: South-Western Pub.
[69] Weinsier, R.L., et al., *The etiology of obesity: relative contribution of metabolic factors, diet, and physical activity.* The American journal of medicine, 1998. **105**(2): p. 145.
[70] Sirard, J.R. and R.R. Pate, *Physical activity assessment in children and adolescents.* Sports Medicine, 2001. **31**(6): p. 439-454.
[71] Short, S.E., et al., *China's one-child policy and the care of children: An analysis of qualitative and quantitative data.* Social Forces, 2001. **79**(3): p. 913-943.
[72] Wei, H., *Growing up under pressure.* Beijing Rev, 2000. **43**: p. 18-21.
[73] Ekblom, B. and P.O. Åstrand, *Role of physical activity on health in children and adolescents.* Acta Paediatrica, 2011. **89**(7): p. 762-764.
[74] Owen, N., et al., *Environmental determinants of physical activity and sedentary behavior.* Exercise and sport sciences reviews, 2000. **28**(4): p. 153.
[75] Sirard, J.R. and M.E. Slater, *Walking and bicycling to school: a review.* American Journal of Lifestyle Medicine, 2008. **2**(5): p. 372-396.
[76] Simmons, D., L.A. Baur, and D. Crawford, *Personal, family, social, and environmental correlates of active commuting to school.* Am J Prev Med, 2006. **30**(1): p. 45-51.