Comparison of Dietary and Physical Activity Behaviors and their Associations with Body Mass Index in Chinese Mothers and Children

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ABSTRACT

TRACY DEARTH WESLEY: Comparison of Dietary and Physical Activity Behaviors and their Associations with Body Mass Index in Chinese Mothers and Children
(Under the direction of Dr. Barry Popkin)

Shifts toward a higher-fat, lower-fiber diet, physical activity reductions, and consequent rises in overweight are occurring in newly industrialized and developing countries experiencing rapid socioeconomic development. Existing research on these dietary and activity changes in newly industrialized countries has primarily focused on adults, and less is known about longitudinal diet and activity behaviors in children. Integration of adult and child diet and activity research is also important given significant parent-child relationships for diet and activity behaviors reported in developed countries. Furthermore, comparison of the relative contribution of diet and activity behaviors toward increased body mass index in adults versus children is needed given differences in the onset and progression of the overweight epidemic in the two population subgroups.

Using longitudinal data from the China Health and Nutrition Survey, we compared dietary and PA behaviors over time and examined how these behaviors relate to increased BMI in mothers versus children. Mother-child associations for dietary, PA, and BMI patterns were also studied. We documented shifts toward diets higher in animal-source foods and lower in grains (i.e., less traditional Chinese diets) in mothers and children, with mothers versus children experiencing more pronounced shifts toward a less traditional Chinese diet over time. However, dietary correlates of increased BMI in mothers and children were less conclusive. PA trends in mothers versus children were disparate. Children reported increases in commuting and leisure-time sports activities over time, whereas mothers reported declines in commuting activity and minimal changes in leisure-time sports activity. A large proportion of mothers and children engaged in high sedentary behavior; high sedentary behavior was associated with increased BMI in mothers. We also found significant mother-child associations for dietary, PA, and BMI patterns that were consistent with those documented in developed countries.

Our research provides an initial look at dietary, PA, and BMI dynamics in mothers versus children within a rapidly changing nutrition and PA environment. Our findings also support dietary interventions and PA promotion focused at the family-level for improved effectiveness and broader public health impact.

This work is dedicated to my family and friends
for their steadfast support and endless encouragement.

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LIST OF ABBREVIATIONS

ASF	Animal-source foods
BMI	Body mass index
CHNS	China Health and Nutrition Survey
CI	Confidence interval
DAG	Directed acyclic graph
EMM	Effect measure modification
FCT	Food composition table
IOTF	International Obesity Task Force
Kcal	kilocalorie
MET	Metabolic equivalent
NCHS	National Center for Health Statistics
NR-NCD	Nutrition-related noncommunicable disease
PA	Physical activity
SD	Standard deviation
SES	Socioeconomic status
SUR	Seemingly unrelated regression
WHO	World Health Organization

I. Introduction

A. Background

Global research on dietary and physical activity (PA) trends reveals universal shifts toward an increasingly Western diet and reductions in occupational, domestic and commuting activities, thus leading to alarming increases in nutrition-related noncommunicable diseases (NR-NCD). These dietary and physical activity changes and consequent rises in NR-NCD are hastened by rapid urbanization, socioeconomic growth, and technological advances. The majority of this research has focused on adult global nutrition and PA dynamics, and less is known about global dietary and PA patterns in children, particularly in newly industrialized and developing countries.

More research on dietary and activity patterns in children within the context of a rapidly a changing nutrition and socioeconomic environment is needed, and integration of this research with adult patterns is important given significant parent-child relationships for dietary intake, PA behaviors, and overweight and obesity. Parental overweight or obesity is associated with accelerated childhood BMI patterns and elevated risks for overweight and obesity during childhood and into adulthood. Dietary research has shown moderate to weak parent-child associations for macronutrient composition measures or intake of specific nutrients. Positive parent-child relationships for sports participation, vigorous activity, and inactivity have also been documented. Longitudinal examination of the parent-child relationship for diet and PA is more limited, as parental dietary and activity patterns are more often examined as they relate to weight changes in children rather than child dietary and activity patterns. Additional longitudinal research within a newly developed country setting is needed to more thoroughly and systematically evaluate the relationship between parent and child dietary and activity patterns over time.

Further investigation into how these dietary and activity behaviors relate to increased BMI in parents versus children is also needed given differences in the onset and progression of overweight and obesity in these two population groups. The onset of increased overweight in adults precedes that found in children; a greater proportion of adults versus children are becoming overweight each year. Despite the initial lag in the onset and progression of child overweight, additional evidence suggests that this gap is closing and child overweight trends are accelerating. While dietary and PA correlates of overweight are well-documented in adults and children, comparison of the relative contribution of these correlates to increased BMI in adults versus children has not been done.

With an overweight and obesity prevalence that has more than doubled over the past couple decades and an estimated 300 million Chinese currently overweight or obese, the Chinese population provided an excellent opportunity for parent-child comparison of dietary and PA patterns and their associations with weight status and BMI change in parents and children. Longitudinal data from the China Health and Nutrition Survey (CHNS) was used to follow 4 cohorts of mother-child pairs across different time periods. The CHNS began in 1989 with subsequent surveys every 2-4 years and includes around 19,000 individuals from roughly 4,400 households from 9 Chinese provinces. Particular emphasis was placed on examination of parent and child dietary and PA patterns by income, residence, and maternal education differentials to enable study of how parent and child dietary and PA patterns change in a country experiencing rapid socioeconomic development.

B. Research Aims

The primary goal of this research was to conduct longitudinal, cross-cohort, comparisons of diet and PA behaviors in mothers and children and to investigate how these behaviors relate to increased BMI in mothers and children. Specific research aims are as follows:

1) Examine dietary intake in mothers versus children over time and across different time periods and investigate associations between dietary intake and socioeconomic factors in mothers and children. We studied dietary intake in 4 separate cohorts of Chinese mother-child pairs followed over 6-7 year time periods using average annual change measures, Spearman partial correlations, random effects models, and seemingly unrelated regression models and estimation.

2) Examine PA and sedentary behavior in mothers versus children over time and across different time periods and investigate associations between PA and socioeconomic factors in mothers and children. We studied PA and sedentary behaviors in 2 separate cohorts of Chinese mother-child pairs followed over 2-4 year time periods using average annual change measures and logistic regression models.

3) Examine the mother-child relationship for BMI and overweight over time and investigate associations between increased BMI with dietary and PA behaviors in mothers and children. We studied diet, PA and BMI in 2 separate cohorts of Chinese mother-child

pairs followed over 2-4 year time periods using Pearson correlation coefficients and logistic, linear, and seemingly unrelated regression models.

II. Literature Review

A. Parents and children have similarities in dietary and activity behaviors.

1. Parent and child dietary behaviors

Cross-sectional studies utilizing different dietary assessment tools, analytical approaches, and population groups have reported correlations between parent and child nutrient intake (Table 2.1) [1-10]. A recent meta-regression analysis found moderate to weak parent-child dietary associations with notable variations with respect to study type, dietary assessment method, and dietary indicators [11]. Parent-child correlations are stronger when more foods are eaten at home, and most studies found stronger correlations between mother-child versus father-child pairs [3, 4, 8]. While one study found stronger parent-child associations among younger versus older children, a second study found similar parent-child associations throughout childhood and adolescence [2, 3]. An estimated 30-50% of the variance in dietary intake for children can be explained by the shared common environment [1, 7].

Past research on parent-child dietary intake is mostly cross-sectional, conducted in developed countries, and focused on macronutrient composition or intake of specific nutrients. Comprehensive longitudinal analysis of the parent-child dietary relationship is more limited. Studies tracking parent-child dietary patterns have only examined a small number of dietary measures and have largely concentrated on the parent-child relationship for fruit and vegetable consumption [12-15]. Several longitudinal studies have also used different assessment tools for parent and child dietary data (i.e., food frequency questionnaire for parents and 24-hour dietary recall for children) [16-18]. Furthermore, parental dietary patterns and the family food environment are more often examined as they relate to BMI or weight status changes rather than dietary patterns in children [16, 19-22].

2. Parent and child PA behaviors

Findings on the relationship between parent and child activity behaviors are strong but less consistent than for the parent-child relationship for dietary behaviors. Significant parent-child associations are found for sports participation, vigorous activity, and inactivity or sedentary behaviors (Table 2.2) [23-31]. Children with two active parents are more likely to participate in sport as compared to children with inactive parents; this relationship was stronger for boys versus girls [23-25]. Parental inactivity, particularly among mothers, is associated with less sport participation in girls and also positively predicts child inactivity [25-27]. Studies that did not find significant relationships between parent-child activity behaviors did show that parental beliefs and support for the child relate to the child's physical activity behaviors [28, 29]. Evidence for the role of social learning variables such as family support for physical activity suggests that parental beliefs and support may be just as important as parental activity behaviors in influencing physical activity behaviors in children [28, 30].

While the majority of the cross-sectional studies examining the relationship between parent and child activity behaviors found significant results, these studies faced some measurement or methodological difficulties. Some of the studies used the same PA assessment methods for parents and children, but others used different questionnaires for parents and children or had the children report on the exercise habits of their parents. The use of different parent and child questionnaires may have compromised the accuracy of the findings and also resulted in the comparison of PA measures that were related but not identical for the parents and children (e.g., the relationship between parental activity level and child sports involvement or child vigorous activity hours). Additionally, when determining child metabolic equivalent (MET) values, one study used the adult compendium for physical activity. While this approach is often used, it underestimates the energy costs of certain activities for children [32, 33]. Furthermore, many of the studies did not consider all potential activity sources when determining physical activity levels for parents and children (e.g., occupational physical activity was not included when determining parental activity level).

B. Parental obesity increases the risk of obesity during childhood and beyond.

Parental overweight and obesity are associated with accelerated childhood BMI patterns and elevated risks for overweight and obesity [34-38]. Statistically significant correlations between parent and child BMI emerge at age 7, with stronger mother-child versus father-child BMI correlations [34-37]. Additionally, a dose-response relationship has been shown for the odds of childhood overweight and the number of parents who are overweight. The odds ratios (OR) (95% CI) for childhood overweight with only an overweight mother were 2.9 (1.6-5.0) for boys and 3.1 (1.7-5.6) for girls; the ORs with only an overweight father were 1.8 (1.1-2.7) for boys and 2.4 (1.5-3.7) for girls. With two obese parents, the ORs for childhood overweight were 7.6 (4.4-13.0) for boys and 6.3 (2.7-14.3) for girls [35]. Furthermore, children with two overweight parents followed from birth to 8 years had higher BMI values over time as compared to children with none or one overweight parent [34].

While having two obese parents more than doubles the risk of childhood obesity, implications of parental obesity persist beyond childhood [39]. For children <3 years, parental obesity status was the main predictor of obesity in adulthood. For children 3-9 years, both parental and child obesity status predicted obesity in adulthood. Parental obesity during early childhood (<10 years of age) was shown to double the risk of obesity during adulthood for both obese and nonobese children [40]. Given how influential parental obesity is during early childhood, we focused on the parent-child relationship for dietary and activity patterns during this critical and impressionable time period.

C. Differences in the onset and progression of overweight and obesity in adults versus children exist.

Global research on overweight prevalence and trends for adults and children reveals important differences regarding the onset and progression of the overweight epidemic in the two population groups. The onset of increased overweight in adults precedes that found in children, with initial overweight prevalence values 2-8 times greater in adults versus children (e.g., overweight prevalence of 13% in Chinese adults versus 5% in Chinese children in 1991). Annual increases in overweight were also greater in adults versus children in newly industrialized and developing countries, resulting in a greater proportion of adults versus children becoming overweight each year. Despite the initial lag in the onset and progression of child overweight, additional evidence suggests that this gap is closing and child overweight trends are accelerating [41]. Improved understanding of overweight prevalence and trend differences in adults and children requires systematic examination into the relationship between BMI with dietary and physical activity (PA) patterns in adults versus children. Dietary and PA correlates of overweight are well-documented in adults and children [42-44], but comparison of the relative contribution of these correlates to increased BMI in adults versus children has not been done.

D. Chinese parents and children are experiencing dietary and PA changes.

1. Dietary changes

Parents and children are shifting away from the traditional Chinese diet to a more Westernized one, which is higher in fat, lower in fiber, and more energy-dense [45-47]. This shift first occurred among China's urban rich, yet some of the more recent changes are occurring among the rural poor (e.g., most rapid increases in edible oil are reported among the poor) [48, 49]. Increased availability and affordability of Western-style foods has resulted in part from changes in tax and import regulations and rapid rises in fast food establishments and supermarkets in both urban and rural areas [49]. Additional changes in Chinese dietary behaviors include increased consumption of snacks and excessive fried food (i.e., >20% of total energy intake from fried food). These behaviors are positively associated with income and are also more prevalent among the urban versus rural Chinese [50].

Little systematic comparison of dietary behaviors in Chinese adults versus children has been done. Research has shown that children are encouraged to eat more meals and larger portions [51]. Furthermore, heavier children are believed to have good nutritional status, be more likely to grow taller, and are a source of pride and an indication of prosperity [51, 52]. Eating at restaurants like McDonald's appears to elevate social status; fast food consumption by children is rapidly increasing [52, 53].

2. Physical activity changes

Changes in physical activity among Chinese parents and children are occurring in different activity domains. Shifts away from high-energy occupations and activity reductions within the same occupation have resulted in decreased energy expenditure from occupational sources [49, 54]. These changes are more pronounced in urban versus rural areas [49]. Reductions in energy expenditure from domestic activities have also occurred given increased ownership of labor-saving devices [54]. These reductions primarily impact adults as Chinese youth do not participate in household chores [55].

Participation by Chinese youth in moderate/vigorous (mod/vig) activity outside of school is negligible; the most frequently reported mod/vig activities are in-school activities and commuting [55, 56]. However, increases in household ownership of motorized transportation will likely result in more passive commuting modes for children and parents [57]. Additionally, increased TV ownership contributes to more leisure-time inactivity [45, 55].

E. Current gaps and research needed.

Improved understanding of longitudinal associations between parent and child diet and activity behaviors and examination into how these behaviors relate to increased BMI in mothers versus children is needed. Past research on parent-child dietary intake and PA behaviors has been mostly cross-sectional, conducted in developed countries, and encountered measurement or methodological issues that may challenge the accuracy of the parent-child comparisons. Examination of the relative contribution of dietary and PA correlates to increased BMI in parents versus children has not been done. Systematic, longitudinal comparison of diet and PA behaviors and their relationships with increased BMI in multiple cohorts of Chinese mother-child pairs provided a unique opportunity to study diet, PA, and BMI dynamics within the context of rapid socioeconomic change. The study design facilitated investigation into the effect of child age on mother and child dietary intake, PA behaviors, and BMI measures and comparison of mother-child dietary and PA behaviors across cohorts with varying penetration of Western media, modern food processing, and technological advances. Research findings provide evidence into how broad-level phenomena such as globalization of the food supply, rapid urbanization, and socioeconomic growth influence the diet, activity, and BMI of parents and children in newly industrialized and developing countries.

Table 2.1. Cross-sectional studies examining the relationship between parent and child dietary intake measures.

Author (Year)	Sample size and child age	Dietary assessment method	Dietary measures	Method	Results
Vauthier *et al.* (1996)[1]	387 French families; children 7-25 y	3-day food record	Total E, %E from macronutrients	Correlation coefficient	Stronger correlations for father-offspring vs. mother-offspring for all measures
Feunekes *et al.* (1997)[2]	1077 Dutch families; children 1-30 y	2-day food record	Total E, total (g) and %E from fat, fatty acids, and cholesterol	Pearson correlation coefficient	Parent-child correlations for all dietary measures between 0.20 and 0.55 (P<0.05); no differences by parent/child gender or child age
Oliveria *et al.* (1992)[4]	106 American families; children 3-5 y	4 sets of 3-day food records	Total E, total (g) and % E from macronutrients, fatty acids, and cholesterol	Pearson correlation coefficient	Significant parent-child correlations for most measures (r <0.50); stronger correlations for mother-offspring vs. father-offspring
Laskarzewski *et al.* (1980)[6]	294 American families; children 6-19 y	24-hour dietary recall	Total E, fats, carbohydrates, and cholesterol	Pearson & Spearman correlations	Parent-child correlations for most measures between 0.15 and 0.28 (P<0.01)
Perusse *et al.* (1988)[7]	375 French families, children 8-18 y	3-day food records	Total E, total (g) and % E from macronutrients	Coefficient of intraclass correlation	Parent-child correlations for all measures between 0.25 and 0.31 ($P \leq 0.01$)
Beydoun *et al.* (2009)[8]	4244 American families; children 2-18 y	Two 24-hour dietary recalls	Total E, food groups (g/day), total (g) and % E from fat, and other nutrients; overall diet quality using the Healthy Eating Index	Pearson correlation coefficient; logistic regression	Parent-child correlations for most measures were between 0.20 and 0.33; Parent-child correlation for overall diet quality was 0.26 (P<0.01); stronger correlations for mother-offspring vs. father-offspring
Wang *et al.* (2009)[10]	121 American mother-child pairs; children 10-14 y	Food Frequency Questionnaire (FFQ)	Total E, food groups (g/day), total fat (g and %E), fiber, and calcium	Spearman correlation coefficient, % of agreement & kappa statistic	Mother-child correlations ranged from -0.24 for total E in boys to 0.30 for total fat in girls; low agreement for parent-child dietary variables; stronger correlations between mother-daughter vs. mother-son
Mitchell *et al.* (2003)[9]	1038 Mexican American families; children 16+ y	FFQ	Total E, % E from macronutrients, and other nutrients	Correlation using the FCOR program on S.A.G.E.	Weak parent-child correlations ranging from 0.05 to 0.14

Table 2.2. Studies examining the relationship between parent and child PA behaviors.

Author (Year published)	Sample size and child age	PA assessment method	PA measures	Method	Results
Eriksson *et al.* (2008)[23]	1124 Swedish families; children 12 y	Questionnaires for parents & children about sport involvement and vigorous exercise	Parental activity level; child sport participation	Logistic regression	Children with 2 active parents had a higher likelihood of participating in sport (OR (95% CI): 3.9 (2.2-6.9) for girls; 8.8 (4.3-18.0 for boys) as compared to children with two inactive parents.
Wagner *et al.* (2004)[24]	3000 French families; children 12 y	Questionnaires for parents and children about sport involvement and sedentary activity	Sport participation and sedentary behavior in parents and child	Logistic regression	Children with 2 parents practicing sport had a higher likelihood of participating in structured PA outside school (OR (95% CI): 1.56 (1.2-2.1) for girls; 1.97 (1.4-2.8) for boys. Children with both parents watching TV>2 hr/day had a higher likelihood of high sedentary behavior (OR (95% CI): 1.95 (1.5-2.6) vs. children with no parents watching TV>2 hr/day.
Sallis *et al.* (1988)[25]	95 Anglo and 111 Mexican-American families; children in 5^{th} & 6^{th} grade	7-day interviewer-administrated Physical Activity Recall	Energy expenditure (EE); time spent in hard or very hard activities during leisure (hard leisure)	Correlation	Significant correlations for EE among Anglo mother-older child pairs, Mexican mother-older and mother-younger-child pairs, and Mexican father-older child pairs; significant mother-child correlations for hard leisure in both families.
Fogelholm *et al.* (1999)[26]	271 Finnish families; children 7-12 y	3-day PA record by parents and child, child questionnaire, and one question on habitual PA for the parents	Parent activity; child vigorous activity hours; parent and child inactivity	Stepwise linear regression	Parental inactivity strongly predicts child inactivity: β-coefficients of 0.25 for mother & 0.16 for father inactivity (P<0.001). Parental activity is a weaker predictor of child vigorous activity hours and total physical activity level: β-coefficients from 0.13-0.25 (P=0.003-0.08).
Kimiecik *et al.* (1998)[29]	81 American families; children 11-15 y	Questionnaires for parents & children about moderate-to-vigorous PA (MVPA)	MVPA in parents and children	Multiple regression	No relationship between parent-child MVPA, but parental beliefs about child's competency and task orientation was significantly related to child's MVPA participation.
Cleland *et al.* (2005)[31]	5929 Australian families; children 9-15 y	Child questionnaire on sports involvement & parental exercise	Parental exercise; child sports involvement; child cardiorespiratory fitness	Linear regression	Parental exercise positively predicts children's sports involvement and cardiorespiratory fitness (P<0.001).

III. Methods

A. CHNS design and analytic sample

1. CHNS design

The CHNS was designed to study the implications of socioeconomic development and government policies and programs on the health and nutritional status of the Chinese population. A multistage, randomized cluster process was utilized to survey around 19,000 individuals from roughly 4,400 households in 9 Chinese provinces that vary in geography, socioeconomic growth, and health indicators. The survey began in 1989; seven surveys have followed in 1991, 1993, 1997, 2000, 2004, 2006, and 2009. New households were added in subsequent surveys to replace households no longer participating in the study, as there is no follow-up with families that move outside of the sampling unit. The survey takes place over 3-days and includes the following components: household information such as demographics and income data, health services and family planning, nutrition and physical activity, and community and food market conditions.

2. Analytic sample

Longitudinal CHNS data was used to follow four cohorts of mother-child pairs over a 6-7 year time period (Figure 1). Three surveys were utilized for each mother-child pair: baseline survey, survey 2-3 years following baseline, and a final survey. For example, Cohort A had baseline measurements in 1991, a second set of measurements in 1993, and a final set of measurements in 1997 (Figure 1). The variability in the length of time followed is dependent on when the surveys were administered. Children age 3-5 years at baseline were followed until age 9-12 years. The early childhood age-group was chosen given how influential parental lifestyle behaviors and obesity are during this developmental period [40]. Chinese children also leave primary school and enter middle school after age 12.

B. Data collection and study variables

1. Data collection

CHNS data were collected using structured questionnaires administered by trained field staff. The field staff completed a 10-day training session and followed a survey protocol similar to that used for the U.S. National Health and Nutrition Examination Surveys conducted by the National Center for Health Statistics (NCHS). CHNS questionnaires were administered to all household members. Parents or primary caregivers completed or assisted with the completion of surveys for children <12 years. Data entry, checking, and cleaning were performed by trained office staff.

Quality control procedures were incorporated into the data collection process. For example, dietary information for each respondent was collected using individual and household collection methods (i.e., individual 24-hour recalls and detailed household food consumption data). The use of these two data collection methods permitted a cross-check on the data quality. When discrepancies were found, the respondent/household was revisited to correct the inconsistency.

2. Study variables

a. *Anthropometry:* Height and weight were directly measured by trained nutritionists. Weight was measured to the nearest 0.1 kg using a calibrated beam scale with participants wearing light clothing and no shoes. Height was measured without shoes to the nearest 0.2 cm by using a portable stadiometer.

b. *Diet:* Dietary data includes household food consumption and individual dietary intake for 3 consecutive days. The 3 days of dietary data collection were randomly allocated to survey participants within each sampling unit, which resulted in fairly evenly balanced dietary data across the 7 days of the week. Individual dietary intake includes 3 consecutive 24-hour recalls by trained nutritionists for all household members. For children <12 years of age, mothers/primary caregivers completed the dietary information. Household food consumption data was determined by the examination of inventory changes from the beginning and end of each day as well as a weighing and measurement approach. The 1991 Food Composition Table (FCT) for China was used to determine nutrient values for dietary data from 2000 and before. The 2002 FCT was used for the 2004 survey; the 2004 FCT was used for the 2006 survey.

c. *Physical activity:* All PA data was self-report. For children <10 years of age, parents were present during the interviews. PA data collected by age-group is described below:

1. Children $\geq$ 6 years: time spent doing sedentary activities before or after school or on the weekend, sports/exercise inside/outside of school, and commuting mode to/from school.

2. Mothers: time spent doing sedentary activities, sports/exercise, commuting mode to/from work or school, and occupational activity.

   With the exception of occupational or in-school activity, the questionnaire format for sedentary, sport/exercise, and commuting activities was similar for mothers and children.

d. Sociodemographic factors: All sociodemographic information with the exception of residence was based on self-report by survey participants in the interviewer-administered questionnaires.

1. Income: Detailed measure of all household activities that involved cash or kind payments. A deflated household per capita income measure was determined by dividing the income measure by the consumer price index.
2. Residence: Urban vs. rural defined based on the administrative district.
3. Maternal education: Highest level of education attained by mother.
4. Age: Date of birth converted to age based on survey date.
5. Gender: Male or female.

Table 3.1 summarizes the study variables and survey years where data on the study variables was available.

Figure 3.1. Mother-child cohorts and corresponding survey years. China Health and Nutrition Survey.

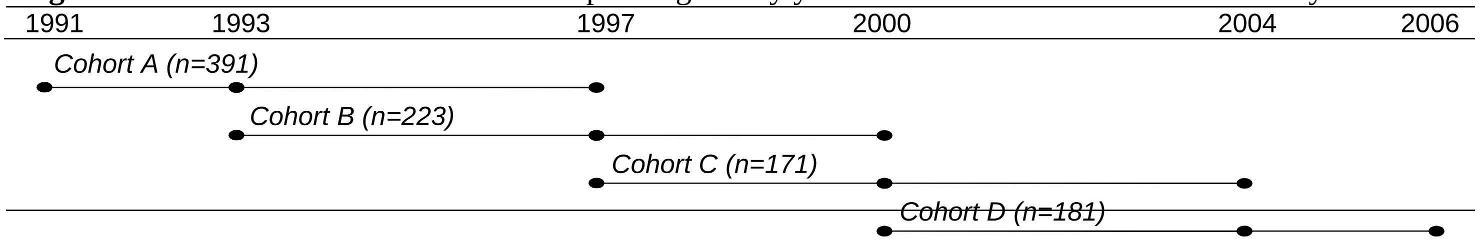


Table 3.1. Summary of study variables and survey years for data collection.

Study variable	1991	1993	1997	2000	2004	2006
Anthropometry	X	X	X	X	X	X
Diet	X	X	X	X	X	X
Physical Activity			X	X	X	X
Sociodemographic factors	X	X	X	X	X	X

IV. Longitudinal, cross-cohort comparisons of dietary intake in Chinese mothers and children

A. Introduction

Global research on dietary change reveals universal shifts toward a diet higher in edible oils and animal-source foods and lower in fiber [58]. Underlying factors driving this dietary shift include expansion of the global mass media and advancements in food processing, production, marketing, and distribution [58-60]. Dietary changes in newly industrialized and developing countries are also enhanced by rapid socioeconomic change and urbanization, thus leading to alarming increases in nutrition-related noncommunicable diseases (NR-NCD) [61, 62]. Limited intervention and policy success preventing further shifts toward an increasingly Western diet and consequent rises in NR-NCD requires improved understanding of global nutrition dynamics within the context of a rapidly changing nutrition and socioeconomic environment.

More effective and well-targeted nutrition policy and intervention efforts require systematic examination of dietary changes in adults versus children. Past research on adult-child dietary intake is mostly cross-sectional and focused on macronutrient composition or intake of specific nutrients [1-10]. A recent meta-regression analysis of these studies found moderate to weak parent-child dietary associations with notable variations with respect to study type, dietary assessment method, and dietary indicators [11]. Longitudinal studies have largely concentrated on the parent-child relationship for fruit and vegetable consumption; parental dietary patterns and the family food environment are more often examined as they relate to weight changes rather than dietary patterns in children [12-17, 21]. Longitudinal research focused on the similarities and differences between parent and child dietary intake is needed to elucidate how shifts toward an increasingly Western diet vary in adults versus children.

To understand how parent and child dietary intake relates to socioeconomic factors and responds to changes in the nutrition environment, we investigated dietary intake in 4 mutually exclusive cohorts of Chinese mother-child pairs. Each cohort was followed over a separate 6-7 year time period using data from the China Health and Nutrition Survey (CHNS): Cohort A: 1991-1997, Cohort B: 1993-2000, Cohort C: 1997-2004, and Cohort D: 2000-2006. The primary study objectives were (1) to compare dietary intake in mothers versus children over time and across different time periods and (2) to examine the relationship between dietary intake and socioeconomic or cohort variables. The study design facilitated investigation into the effect of child age on mother and child dietary intake and comparison of mother-child dietary intake across cohorts with varying penetration of Western media, modern food processing, and supermarket growth. The cohorts also spanned the last couple decades in China, which enabled examination of how mother and child dietary intake changes during rapid socioeconomic development.

B. Methods

1. Data and subjects

Longitudinal data from the CHNS were used. The CHNS began in 1989 with subsequent surveys every 2-4 years. A multistage, randomized cluster design was utilized to survey around 4,400 households and roughly 19,000 individuals from 9 Chinese provinces that vary in geography, socioeconomic growth, and health indicators. The study met the standards for the ethical treatment of participants and was approved by the University of North Carolina at Chapel Hill and the Institute of Nutrition and Food Safety, Chinese Center for Disease Control and Prevention. Additional CHNS details are available in previous publications [63-65].

Our study sample included 4 mutually exclusive cohorts of biological mother-child pairs followed over 6-7 year time periods. Each cohort had survey measurements from 3 points in time (Figure 3.1). Children in each cohort were 3-5 years of age at baseline and followed until 9-12 years of age. Inclusion criteria included dietary data for mothers and children from 3 time points, resulting in a study sample of 966 mother-child pairs and a follow-up rate of 44%. A likely contributor to the lower follow-up rate was the stringent inclusion criteria requiring 6 complete sets of dietary data gathered over time for each mother-child pair. However, mothers and children lost to follow-up did not significantly differ from the study sample with respect to baseline residence, income, maternal education, child's age, and all dietary intake variables. Significant differences were found for maternal age and child's gender ($P<0.05$). Adjustment for maternal age and child's gender was done, as gender differences with respect to dietary fat intake among Chinese children have been shown [47]. No adjustments for sampling design were done, since past CHNS research found that adjustments were necessary only when community level factors were examined [66].

2. Measures

CHNS data were collected using structured questionnaires administered by trained field staff to all household members. Parents or primary caregivers completed dietary information for children <12 y, and the same dietary assessment tools were used for mothers and children. Age and gender were self-reported; details on SES measures have been previously published [67]. Dietary data included household food consumption data and 3 consecutive 24-hour recalls, with data collection randomly allocated during the week. The 1991 Chinese Food Composition Table (FCT) was used to determine nutrient values for dietary data from 2000 and before. The 2002 FCT was used for the 2004 survey; the 2004 FCT was used for the 2006 survey. Mean daily dietary values were determined using the 3 days of dietary information. The CHNS dietary assessment approach has been shown to reduce the effects of measurement error and accurately capture usual energy intake [68, 69].

Dietary variables were the percentages of total energy (% E) from animal-source foods (ASF), fats/oils, and grains. The % E from ASF and grains were determined using the 24-hour recall data and food groups specified by the China Food Grouping System (Appendix 1). Animal-source foods included beef, pork, poultry, meat products, eggs, and egg products and excluded animal fats, such as beef tallow or lard. Grains included rice, wheat flour and wheat products, and corn flour and corn products. Rice- or wheat-based cakes, cookies, and pastries were excluded, since these foods represent more processed grains less characteristic of the traditional Chinese diet. The % E from fats/oils consisted of plant oils, beef tallow, lard, and butter was determined using household food consumption data. To determine individual oil consumption, the proportion of the individual's intake of household foods cooked with fats/oils relative to the total household intake of foods cooked with fats/oils was multiplied by the total amount of fats/oils used by the household. The individual consumption of fats/oils in kilocalories was divided by the total daily energy intake to determine the % E from fats/oils. Dietary values were excluded if they fell beyond the far upper or lower fences of the box and whisker plots as determined separately for mothers and children by cohort and survey year.

3. Statistical analysis

Significant differences across the cohorts with respect to baseline characteristics were examined using one-way ANOVA and chi-squared tests. Mother-child differences for dietary variables were tested using the Wilcoxon-Mann Whitney test. Mother-child comparison of changes in the % E from ASF, fats/oils, and grains was examined using an average annual change measure. Since each cohort had 3 survey time points, the reported average annual change measure was the mean of the average annual change measures from baseline to midpoint and from midpoint to follow-up. Each annual change measure was calculated by dividing the dietary value difference from the 2 survey time points by the number of years between the 2 survey time points. Spearman partial correlations were also calculated to examine the mother-child dietary relationship at each time point and by cohort. Significant differences between correlations were based on Fisher's z transformation of the correlations.

For mother-child comparison of the effects of SES variables, cohort, and interactions between SES variables and cohort on the dietary outcomes, a two-step approach was utilized. First, we used maximum likelihood random effects models with backward deletion to separately determine the most parsimonious equations for examining the longitudinal relationship between the dietary outcomes and SES and cohort variables in mothers and children. Interaction terms with the largest standard error relative to their p-value were removed first, and likelihood ratio tests were done comparing the reduced model to the full model. These models separately accounted for the correlation in repeated measurements for individuals (range 0.16-0.35). For the % E from grains and fats/oils, the final equations were then used in seemingly unrelated regression (SUR) models. The SUR models enabled testing of the equality of the coefficients for the mother and child equations with consideration of correlated error terms. For the % E from ASF, the final equations were then used in a tobit model followed by seemingly unrelated estimation. The direct and indirect effects of the SES or cohort variables were determined using the nonlinear combinations of estimators command (nlcom) in Stata providing regression coefficients (95% CI).

C. Results

Significant differences across the cohorts were found for child's age, mother's age and education, mothers' and children's total dietary intake, and annual household income (P<0.05) (Table 4.1). No significant differences across the cohorts were found for child's gender, maternal BMI, or household residence.

Mothers and children in the latest versus earliest cohort consumed a less traditional diet at all time points, particularly for the % E from ASF and grains measures (Figure 4.1). Significant differences were found between mothers and children in both cohorts for the % E from ASF and grains across all child's age periods ($P<0.05$). The % E from fats/oils was not significantly different across most mother-child comparisons.

In the earliest and latest cohorts, mothers experienced average annual changes in the % E from ASF over 2 times greater than those found in children (Figure 4.2). Average annual changes in the % E from fats/oils were less distinct between mothers and children. For the % E from grains, mothers (versus children) in both cohorts experienced greater annual reductions in grains. Comparison by cohort showed greater annual increases in the % E from ASF for mothers and children in the latest cohort, contrasting changes in the % E from fats/oils, and greater reductions in the % E from grains for mothers and children in the earliest cohort.

Mother-child correlations for the dietary variables ranged from 0.46 to 0.89 ($P<0.001$)(Table 4.2). Increases in mother-child correlations were found with increasing child age group across all cohorts for the % E from ASF, fats/oils, and grains variables. Significant differences in the mother-child correlations for all food groups were found between the earliest and latest cohorts at child age 3-5 years, indicating less similar mother-child diets in the latest survey years ($P<0.05$).

The relationships between the % E from food groups and SES or cohort variables for mothers and children were examined (Table 4.3). Testing of the equality of mother-child coefficients indicated that urban (versus rural) and higher levels of maternal education were associated with significantly greater % E from fats/oils in mothers versus children (P<0.01). In contrast, SES and cohort variables do not differentially affect the % E from ASF or grains in mothers versus children. Similar increases in the % E from ASF and decreases in the % E from grains for mothers and children were found with urban (versus rural) residence, higher levels of maternal education, and later cohorts. Significant differences in the % E from ASF and grains were found for mothers and children with respect to the age group of child. As compared to when the children were 3-5 years, mothers (versus children) consumed a higher % E from ASF (1.65 and 0.15%, respectively) and lower % E from grains (-4.01 and -1.55%, respectively) when the children were 9-12 years. No significant relationship was found for mothers or children between income and the dietary variables.

D. Discussion

Our study provided a more comprehensive understanding of mother and child nutrition dynamics, with particular emphasis on how child age, SES and cohort factors relate to dietary intake for mothers and children. We found that while children were earlier adopters and maintainers of a less traditional diet, mothers experienced greater shifts away from the traditional Chinese diet with increasing child age. Despite these differences, we also found considerable similarities between mother-child dietary intake patterns and their relationship with SES variables. Furthermore, a comparable cohort effect was shown for mothers and children, which indicated markedly less traditional diets for mothers and children in the later versus earlier cohorts.

Significant mother-child differences in the % E from ASF and grains were found across all child age periods, with children versus mothers adopting and maintaining a less traditional Chinese diet over time. It is hypothesized that these differences are influenced in part by dietary implications of the "compensation syndrome." Given their past experiences during the Cultural Revolution, Chinese parents want to give their children everything they did not have as a child and are now able to provide their children with diverse and plentiful foods [52, 70]. Dietary implications of this are hypothesized to include dietary sacrifices made by parents toward their children, which may in part explain why we found children preceding mothers in having a diet higher in ASF and lower in grains. Later shifts toward a less traditional diet in mothers are hypothesized to be consequent of the increased affordability, accessibility, and availability of more Western foods.

Examination of mother-child correlations for the dietary variables showed moderate to strong correlations (range 0.46-0.89). These findings are stronger as compared to past studies, which may in part be a consequence of dietary assessment or methodological differences among the studies or indicative of more similar dietary patterns in Chinese mothers and children [2, 4, 6-11]. The mother-child dietary intake associations found in our study highlight the need for nutrition policy and intervention efforts targeted at the family-level.

A comparable relationship was found between SES factors and the diets of mothers and children. Urban (versus rural) residence was associated with a less traditional diet for mothers and children, a finding that is well-supported by previous dietary research in China [50, 65, 71]. We also found that increasing levels of maternal education were associated with increasingly unhealthy diets of mothers and children. This relationship has been documented in other studies and demonstrates the Chinese lifestyle transition associated with SES [50, 65, 72]. Chinese of higher SES have more exposure to and a greater ability to adopt a more Westernized lifestyle; the level of education in China is not high enough to prevent the shift toward a less healthy lifestyle [72]. While this shift has historically been more characteristic of Chinese of higher SES, rapid socioeconomic change has also accelerated similar lifestyle changes among those of lower SES [48, 49].

Our study further documented dietary intake similarities between mothers and children with respect to cohort. As compared to cohort A, mothers and children in cohorts C and D had a markedly less traditional Chinese diet. While these findings are similar to past dietary trend research in China [49, 73], the distinct dietary differences in the later versus earlier cohorts are of particular interest. Probable contributors to this cohort difference are the rapid growth of multinational and domestic supermarkets, rapid increase in television ownership, and increasing presence of the Western media in the mid- to late 1990s [49, 60, 74, 75].

There are some study limitations that necessitate explanation. Our stringent inclusion criteria raise the concern of selection bias associated with loss to follow-up. However, previous longitudinal research on dietary intake patterns in Chinese youth using CHNS data found insignificant changes in estimates after correcting for selection bias [65]. A second limitation is the possibility of inaccurate dietary assessment in mothers and children, but research on the CHNS dietary assessment approach found no underreporting by men and only a small degree of underreporting (8%) by women [68]. A third limitation is the potential for same-source bias. A mother self-reporting her own dietary intake and that of her child could lead to falsely high mother-child correlations for dietary intake. A final study limitation was the lack of consideration for dietary intake patterns of grandparents. Grandparents play an influential role on children's eating behaviors [51, 70], thus inclusion of the dietary patterns of grandparents would have contributed to a deeper understanding into how children's dietary patterns are shaped by the family dietary environment.

Our study was unique in examining the longitudinal mother-child dietary intake across separate periods of time. Our selection of dietary intake variables expanded upon existing dietary research in China and was dually advantageous: relative measures of dietary intake allow adjustment for age and gender, tracking of dietary patterns, and often adjust for reporting errors [65]; selection of the specific food groups allowed us to examine dietary shifts characterizing a less traditional Chinese diet. The extensive nature of the CHNS dietary data and use of the same dietary assessment tools in mothers and children enabled more accurate and systematic examination of dietary intake patterns in mothers and children, resulting in new insight into how mother and child dietary intake evolves over periods of rapid socioeconomic growth in China.

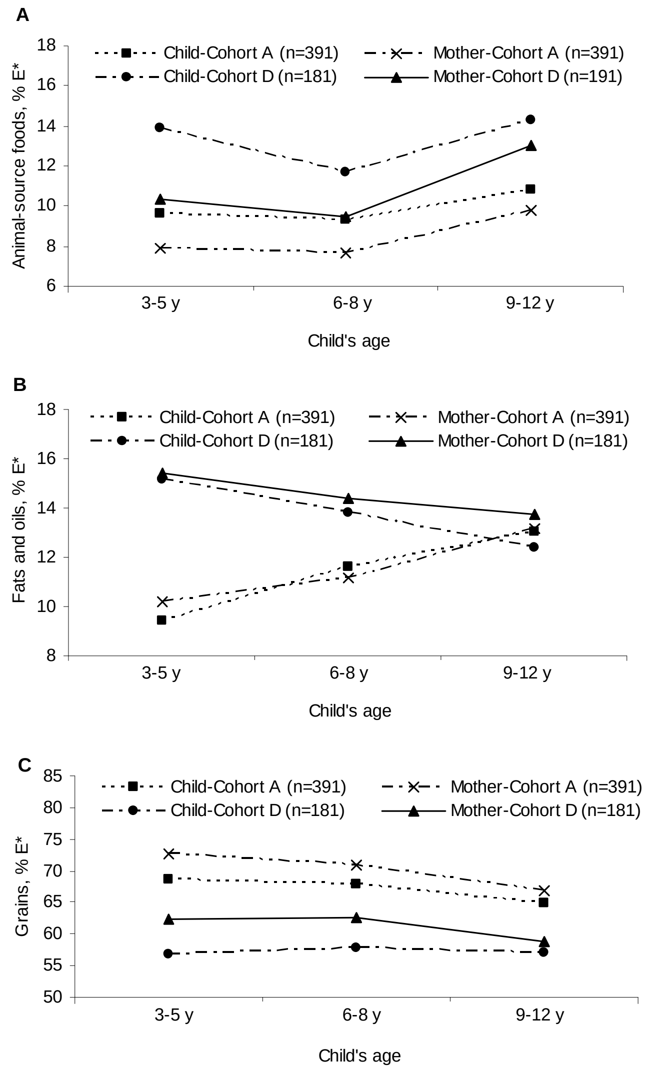
While similarities in mother-child dietary patterns support the need for nutrition interventions focused at the family-level, mother-child dietary differences suggest that these interventions must also be mindful of cultural norms and parental attitudes toward child nutrition. The success of these interventions will continue to be challenged by a nutrition environment where more Western foods are increasingly available, accessible and affordable. We postulate that there would be considerable overlap in our findings with mother-child dietary research in other countries experiencing rapid economic development and nutritional environment changes, but more research is needed. Future research must also integrate findings on mother and child dietary intake with other underlying determinants of energy balance, such as physical activity patterns, in order to better understand their relationship to overweight and obesity in adults and children.

Table 4.1. Baseline characteristics of mother-child pairs by cohort. China Health and Nutrition Survey.[1,2]

	Cohort A	Cohort B	Cohort C	Cohort D
Survey years	1991, 1993, 1997	1993, 1997, 2000	1997, 2000, 2004	2000, 2004, 2006
N	391	223	171	181
Child's gender, *% male*	61.6	58.3	59.7	51.4
Child's age, *y**	4.3 ± 0.9	3.9 ± 0.6	4.4 ± 0.9	4.3 ± 0.9
Children's energy intake, kJ/d[†]				
3-5 y	5991 ± 2030	5527 ± 2085	5149 ± 2033	5206 ± 2229
6-9 y	6826 ± 2235	6761 ± 2050	6893 ± 2729	6726 ± 2402
10-12 y	7749 ± 2144	7850 ± 2299	8144 ± 2672	6882 ± 2152
Mother's age, *y**	31.7 ± 5.1	31.7± 4.8	30.3 ± 3.6	30.6 ± 3.7
Mother's BMI, kg/m^2	21.6 ± 2.8	21.5 ± 2.4	22.0 ± 3.1	21.8 ± 2.6
Mothers' energy intake, kJ/d[†]				
Children 3-5 y	10975 ± 2799	10821 ± 3396	9317 ± 2556	9309 ± 3135
Children 6-9 y	10767 ± 3350	9496 ± 2669	9437 ± 2707	9194 ± 2559
Children 10-12 y	9442 ± 2379	9377 ± 2673	9252 ± 2699	8721 ± 2493
Mother's education, *%**				
None/Primary school	45.8	49.8	50.0	45.4
Middle school	35.4	35.0	33.3	36.8
High school	16.7	13.0	11.3	8.6
College, technical or higher	2.1	2.2	5.4	9.2
Annual household income, *yuan*[3]*	9556 ± 8232	10502 ± 8840	13491 + 11099	16792 + 17034
Household residence, *% rural*	74.7	78.5	74.9	77.4

[1]Values are mean ± SD or percentage.
[2]Data were missing for mother's age (n=9), mother's BMI (n=96), mother's education (n=12), and household income (n=31).
[3]Annual household income inflated to 2006 yuan currency values.
*Different across cohorts, $P<0.001$.
[†]Different across cohorts, $P<0.05$.

Figure 4.1. Percentage of energy from animal-source foods, fats and oils, and grains for mothers and children over time in the earliest and latest cohorts. China Health and Nutrition Survey.



*Mother-child differences for all child's age periods by cohort were found for the % E from ASF and grains variables (P<0.05). For the % E from fats and oils, mother-child differences were found for Cohort A (child's age 6-8 y) and Cohort D (child's age 9-12 y) (P<0.05).

Figure 4.2. Average annual changes in the percentage of energy from animal-source foods, fats and oils, and grains for mothers and children in the earliest and latest cohorts. China Health and Nutrition Survey.

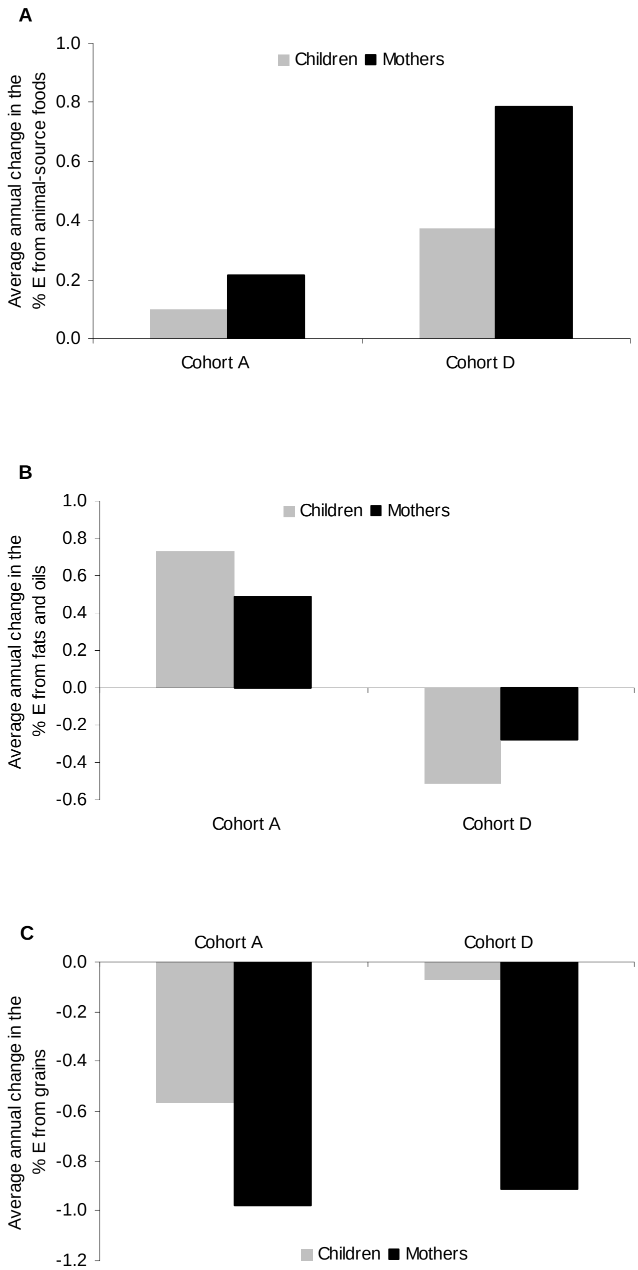


Table 4.2. Mother-child correlations for the % E from animal-source foods, fats and oils, and grains by cohort. China Health and Nutrition Survey[1,2]

	% E from animal-source foods			% E from fats and oils			% E from grains		
	Child age 3-5 y	Child age 6-8 y	Child age 9-12 y	Child age 3-5 y	Child age 6-8 y	Child age 9-12 y	Child age 3-5 y	Child age 6-8 y	Child age 9-12 y
Cohort A	0.87	0.88	0.93	0.66	0.77	0.84	0.74	0.83	0.85
Cohort B	0.86	0.89	0.89	0.69	0.76	0.80	0.73	0.83	0.83
Cohort C	0.83	0.86	0.89	0.68	0.75	0.80	0.82	0.67	0.77
Cohort D	0.74*	0.87	0.80*	0.62*	0.75	0.82	0.46*	0.78	0.81
All Cohorts	0.84	0.87	0.89	0.68	0.77	0.82	0.73	0.80	0.83

[1]Correlations adjusted for child's gender and age, mother's education and age, annual household income and residence.
[2]All correlations different from 0, *P* <0.001.
*Different from Cohort A, *P* <0.05.

Table 4.3. Associations between socioeconomic or cohort variables and the percentage of energy from animal-source foods, fats and oils, and grains. China Health and Nutrition Survey.[1]

	Animal-source foods		Fats/oils		Grains	
	Child	Mother	Child	Mother	Child	Mother
Household residence						
Rural	Ref	Ref	Ref	Ref	Ref	Ref
Urban	3.22 (2.93, 3.52)*	3.42 (3.14, 3.70)*	1.46 (1.27, 1.65)*#	2.82 (2.63, 3.00)* #	-5.92 (-6.08, -5.75)*	-6.11 (-6.30, -5.92)*
Annual household income[2]	-0.14 (-0.88, 0.61)	0.08 (-0.63, 0.78)	-0.32 (-0.83, 0.19)	-0.46 (-0.95, 0.03)	0.36 (-0.52, 1.23)	0.17 (-0.65, 0.99)
Maternal education						
None/primary	Ref	Ref	Ref	Ref	Ref	Ref
Middle school	3.91 (2.90, 4.93)*	3.12 (2.75, 3.48)*	0.23 (-0.43, 0.91)#	1.18 (0.53, 1.83)*#	-4.53 (-4.69, -4.36)*	-4.64 (-4.80, -4.49)*
High school	5.12 (3.84, 6.41)*	5.25 (4.04, 6.46)*	0.86 (-0.09, 1.81)#	1.74 (0.82, 2.66)*#	-6.31 (-7.96, -4.66)*	-6.68 (-6.76, -6.59)*
Technical or higher	8.07 (8.00, 8.15)*	6.39 (4.43, 8.36)*	0.17 (-1.46, 1.80)#	2.69 (2.65, 2.74)*#	-11.84 (-11.92, -11.76)*	-13.16 (-15.84, -10.47)*
Cohort						
Cohort A	Ref	Ref	Ref	Ref	Ref	Ref
Cohort B	-0.56 (-0.90, -0.22)‡	0.05 (-0.32, 0.42)	0.80 (0.48, 1.11)*	1.70 (1.39, 2.00)*	-1.87 (-2.31, -1.44)*	-2.23 (-2.65, -1.95)*
Cohort C	1.52 (1.20, 1.84)*	0.54 (0.21, 0.87)‡	2.97 (2.68, 3.25)*#	4.56 (4.28, 4.84)*#	-8.79 (-9.18, -8.40)*	-7.99 (-8.30, -7.68)*
Cohort D	1.24 (0.83, 1.66)*	0.65 (0.22, 1.08)†	6.43 (6.11, 6.75)*	6.20 (5.89, 6.51)*	-9.83 (-10.29, -9.37)*	-9.83 (-10.20, -9.45)*
Age of child						
Child 3-5 y	Ref	Ref	Ref	Ref	Ref	Ref
Child 6-8 y	-1.06 (-2.15, 0.03)#	-0.40 (-1.36, 0.56)#	1.15 (0.86, 1.45)*	0.75 (0.46, 1.03)*	0.42 (0.09, 0 .75)‡	-0.67 (-1.86, 0.52)
Child 9-12 y	0.15 (-0.95, 1.25)#	1.65 (0.68, 2.63)†#	2.29 (1.98, 2.56)*	2.07 (1.78, 2.37)*	-1.55 (-1.89, -1.21)*#	-4.01 (-5.21, -2.81)*#

[1]Regression Coefficient (95% Confidence Interval).
[2]A one unit increase in income is equal to 1000 yuan.
**P*<0.0001, †*P*<0.01, ‡*P*<0.05
#Rejection of null hypothesis that mother and child coefficients are equal (*P*<0.01).

V. Longitudinal, cross-cohort comparison of physical activity patterns in Chinese mothers and children

I. Introduction

Continued global reductions in occupational, domestic and commuting activities are inevitable based on rapid urbanization, socioeconomic growth, and technological advances [58, 60, 76, 77], thus leisure-time physical activity (PA) is increasingly important for chronic disease prevention. However, one in five adults worldwide does not meet the global recommendations for PA and is considered physically inactive [78]. Less is known about global PA patterns in children, particularly in newly industrialized and developing countries experiencing rapid socioeconomic growth [79].

More research on PA patterns in children is needed, and integration of this research with adult PA patterns is important given the positive relationships between parent and child sports participation, vigorous activity and inactivity [24, 26, 27, 31, 79, 80]. Children with two active parents are more likely to participate in sport as compared to children with inactive parents; parental inactivity strongly predicts child inactivity [23, 24, 26, 31]. While these studies were conducted in developed countries and were mostly cross-sectional, some longitudinal research has shown that the parent-child PA relationship weakens or no longer exists with increasing child age [81-83]. Additional longitudinal research is needed to more thoroughly evaluate the relationship between parent and child PA over time within a newly industrialized country setting.

Past research on parent-child PA dynamics in China found parental encouragement and role modeling to be positively related to child's attraction to and participation in PA [84-86]. Parental influence on child PA in China may be explained in part by parental "training" or guan, a more controlling parenting style stressing hard work and self-discipline [85].

Using longitudinal data from the China Health and Nutrition Survey (CHNS), we examined PA behaviors in 2 separate cohorts of mother-child pairs followed over a 2-4 year time period. Comparable mother-child PA behaviors included commuting activity, leisure-time sports activity, and sedentary behavior. Use of the two cohorts permitted examination into how mother and child PA changes across different time periods. Our primary study objectives were (1) to compare PA trends in mothers and children, (2) to examine associations between mother and child PA behaviors over time and (3) to examine the relationships between PA behaviors and socioeconomic variables in mothers and children.

B. Methods

1. Data and Subjects

We used longitudinal data from the CHNS. The CHNS began in 1989 with subsequent surveys every 2-4 years. A multistage, randomized cluster design was utilized to survey around 4,400 households and roughly 19,000 individuals from 9 Chinese provinces that vary in geography, socioeconomic growth, and health indicators. No adjustments for sampling design were done, as past research found that adjustments were necessary only when community level factors were examined [66]. Additional CHNS details are available in previous publications [49, 67]. The study met the standards for the ethical treatment of participants and was approved by the IRB's of the University of North Carolina at Chapel Hill and the Institute of Nutrition and Food Safety, Chinese Center for Disease Control and Prevention.

Our study sample included 2 separate cohorts of biological mother-child pairs followed over a 2 or 4-year time period (2000 Cohort: 2 measurement occasions 2000 & 2004; 2004 Cohort: 2 measurement occasions 2004 & 2006). Children in the 2000 Cohort were 6-8 years of age at baseline; children in the 2004 Cohort were 7-9 years of age at baseline. The cohorts were determined based on 2 factors: (a) The cohorts are an extension of previous dietary research in the same mother-child pairs; (b) The sample was restricted to children who remained <12 years of age throughout the study, since children ≥ 12 years of age leave primary school and enter middle school (i.e., potential for different commuting distances).

The analytic sample included mother-child pairs who had complete PA data at both measurement occasions. Complete PA data was defined as mother and child measurements for commuting and leisure-time sports at both measurement occasions and measurements for sedentary behavior at the second measurement occasion. Since data on sedentary behavior in adults was first collected in the 2004 CHNS, only cross-sectional mother-child comparison of sedentary behavior was feasible. A total of 872 mother-child pairs had at least some mother or child PA data at baseline, while 353 mother-child pairs (40%) had complete PA data. Mother-child pairs with incomplete PA data did not significantly differ from the analytic sample with respect to baseline residence, income, maternal education, child's age, and all PA variables, but significant differences for child's gender were found ($p<0.05$).

2. Measures

CHNS data were collected using structured questionnaires administered by trained field staff to all household members. Parents or primary caregivers completed or assisted with the completion of surveys for children <10 years. Details concerning the socioeconomic measures (i.e., residence, income, maternal education) have been previously published [49, 67].

Children and mothers were asked about their participation and weekly time spent in commuting to and from school or work and in specific groups of sports activities and sedentary behaviors. Commuting activity included biking or walking to school or work. Leisure-time sports were grouped into 4 main categories: gymnastics, track and field/swimming, ball sports (e.g., tennis, basketball, soccer), and other sports (e.g., martial arts, tai chi). Sedentary behavior consisted of 4 main categories: TV/DVD watching, board/video games, extracurricular reading and writing, and computer usage. While children were asked about their participation and time spent doing homework, the measure was not included in the sedentary category to enable mother-child comparability of sedentary behavior.

The main PA variables were total metabolic equivalent hours per week (MET-hrs/wk) from commuting, leisure-time sports, and sedentary behaviors. First, each reported activity was assigned a MET value using the Compendium of Energy Expenditures for Youth for children and the Compendium of PA for mothers [32, 33]. Average MET values were used for activity categories such as ball sports or other sports. The MET value for each activity was then multiplied by the total time spent per week (hrs/wk) in the activity, resulting in the MET-hrs/wk measurement. Implausible high values were examined within the context of each activity domain and its categories and replaced with plausible maximum values using domain and category-specific criteria.

High versus low activity categories based on the World Health Organization's Global PA Recommendations or on time-based cut-points were created to facilitate interpretation of the findings and applicability to PA research, policy, and intervention efforts [87]. High commuting activity was defined as the MET-hrs/wk equivalent of ≥30 minutes/day of biking or walking. High leisure-time sports activity for children was defined as the MET-hrs/wk equivalent of at least 60 minutes of moderate- to vigorous-intensity PA daily, with vigorous-intensity PA at least 3 times per week [87]. High leisure-time sports activity for mothers was defined as the MET-hrs/wk equivalent of at least 150 minutes of moderate-intensity PA per week, at least 75 minutes of vigorous-intensity PA per week, or an equivalent combination of moderate- to vigorous-intensity PA [87]. High sedentary behavior for mothers and children was defined as the MET-hrs/wk equivalent of ≥2 hours/day of sedentary behavior.

3. Statistical Analysis

All analyses were conducted using Stata version 11.0 (Stata Corporation, College Station, TX, USA). Significant differences between the cohorts with respect to baseline characteristics were examined using chi-squared and t tests. The Wilcoxon signed rank test was used to examine differences in the total MET-hrs/wk from each activity domain or activity category from baseline to follow-up. Average annual changes in PA were calculated by subtracting the average MET-hrs/wk from the first time point from the average MET-hrs/wk from the second time point and then dividing the result by the difference in the years between the 2 survey time points. Average annual changes were determined separately in each cohort in order to examine how PA changes in mothers and children with increasing child age.

To examine associations between mother and child PA behaviors over time, we used logistic regression models. Separate logistic regression models at baseline and follow-up examined how high (versus low) maternal activity was associated high child activity for commuting, leisure-time sports, and sedentary categories. Logistic regression was done given the large percentage of mothers reporting no commuting or leisure-time sports activities (36% and 93%, respectively). We developed a directed acyclic graph (DAG) to qualitatively understand the relations between covariates and mother and child PA or sedentary behavior and to guide our analysis [88]. Child's gender was identified for potential effect measure modification (EMM) and was informed by research showing varying mother-child PA associations by child's gender [23, 24]. Comparison of stratum-specific estimates and results from Breslow-Day tests of homogeneity did not indicate that child's gender modified the mother-child PA or sedentary behavior association. Socioeconomic and cohort variables, maternal and child age, and child's gender were included as confounders based on our DAG as well as supporting research [49, 55, 74, 77, 81-83].

To examine cross-sectional relationships between PA behaviors and socioeconomic variables in mothers and children, we used logistic regression models. Logistic regression models examined how socioeconomic variables were associated with high commuting, leisure-time sports, or sedentary behaviors. Models for commuting and leisure-time sports activities used data from both measurement occasions, and models for sedentary behavior used data at follow-up. Separate models were run in mothers and children for commuting, leisure-time sports, and sedentary categories. Child's gender was again assessed for EMM in all child models but was not found to modify the associations based on stratum-specific estimates comparisons and Breslow-Day tests of homogeneity. Child models controlled for cohort, child's gender and child's age based on DAG analysis and supporting research [55, 89]; models for mothers controlled for cohort and maternal age also based on our DAG and supporting research [76, 90].

C. Results

Significant differences between the cohorts were found for child's age, mother's age and annual household income ($P<0.001$) (Table 5.1). Children and mothers in the 2000 Cohort were younger than children and mothers in the 2004 Cohort. The mean household income inflated to 2006 yuan currency values was higher in the 2004 Cohort versus the 2000 Cohort.

1. Descriptive

Whereas commuting MET-hrs/wk increased for children over time, we found temporal declines in MET-hrs/wk for mothers ($P<0.001$) (Table 5.2). Children reported increases in MET-hrs/wk from biking and decreases in MET-hrs/wk from walking, while mothers reported decreases in MET-hrs/wk from both activities ($P<0.05$). The proportion engaged in high commuting activity increased for children from baseline to follow-up but decreased for mothers (Table 5.3).

Temporal increases in MET-hrs/wk from leisure-time sports activity were found for mothers and children, but average annual changes for children were at least 4 times greater than those found for mothers (Table 5.2). With respect to categories of leisure-time sports activity, the most notable increases from baseline to follow-up for children were found for ball sports (e.g., MET-hrs/wk for ball sports increased from 1.5 to 8.8 for children in the 2000 Cohort and from 3.1 to 6.7 for children in the 2004 Cohort). The proportion reporting high leisure-time sports activity increased over time for children but was less consistent over time for mothers across the cohorts (Table 5.3).

Sedentary MET-hrs/wk for children were roughly 6-7 MET-hrs/wk higher as compared to that of mothers, which translates into 4-5 more hrs/wk of sedentary behavior for children versus mothers (Table 5.2). Sedentary behavior for mothers and children was primarily comprised of TV/DVD watching. A higher proportion of children versus mothers engaged in high sedentary behavior (Table 5.3).

2. Modeling associations between mothers' and children's PA or sedentary behavior

High commuting activity in mothers was associated with an increased likelihood of high commuting activity in children at baseline and follow-up ($P<0.05$) (Table 5.4). For leisure-time sports activity, children with mothers engaged in high sports activity had a greater likelihood of high sports activity at baseline ($P<0.05$), but this relationship did not persist at follow-up. High maternal sedentary behavior was inversely associated with high sedentary behavior in children ($P<0.05$).

3. Modeling associations between socioeconomic variables with PA or sedentary behavior in mothers and children

We found few significant associations between socioeconomic factors and high commuting, leisure-time sports, or sedentary behaviors in mothers and children. Rural children were less likely than their urban counterparts to engage in high commuting activity ($P<0.01$) (Table 5.5). Mothers with a technical, college, or higher education had a greater likelihood of high leisure-time sports activity and high sedentary behavior versus mothers with none or a primary school education ($P<0.05$).

D. Discussion

Using unique maternal and offspring PA and sedentary behavior data from a country undergoing major economic, social, and environmental change, we found disparate trends in mothers and their children. Whereas commuting and leisure-time sports activities increased for children over time, commuting activity declined and there was minimal change in leisure-time sports activity for mothers over time. In general, sedentary behavior was high across mothers and their children over time. Overall there were positive mother-child associations for commuting and leisure-time sports activities and a negative mother-child association for sedentary behavior.

Temporal shifts toward increased leisure-time sports activity were more pronounced in children versus mothers. Increased leisure-time sports activity in children is hypothesized to result in part from national PA initiatives, such as the Nationwide Physical Fitness Program. The 15-year-long program began in 1995 and promoted PA in Chinese youth through the establishment of juvenile sports clubs and new public sporting facilities [91, 92]. Concurrent to national initiatives is the growing popularity of competitive sports like basketball, which is also supported by the government construction of 600,000 basketball courts across the country [93, 94]. While increased leisure-time sports activity in Chinese youth is encouraging, minimal sports activity in mothers coupled with the continued modernization of occupational and domestic activities necessitates more intensive PA promotion efforts for Chinese adults.

Our study documented a significant positive mother-child relationship for high leisure-time sports activity at baseline but no association at follow-up. This finding is consistent with previous research showing decreased associations between parent and child sports activity with increasing child age [81-83]. While decreased mother-child associations with increasing child age may be consequent of more PA promotion efforts targeted at children, it also may be that maternal PA is less influential on child PA patterns with increasing child age. Further longitudinal investigation into how other parental factors (e.g., parental beliefs and support) relate to child PA patterns is needed, particularly since cross-sectional research has shown these factors to be significantly correlated with child PA [29, 30, 80, 95]. Improved understanding into how these factors influence child PA patterns is important for more effective family-based interventions promoting child PA.

The association between socioeconomic factors with PA and sedentary behaviors differed for mothers and children. Maternal education was significantly associated with a greater likelihood of high leisure-time sports activity and high sedentary behavior in mothers, similar to other research in China [74, 76, 96]. However, maternal education was not significantly associated with PA in children. This is similar to findings from a review of PA correlates in youth (4-12 years), which did not find parental education to be a significant correlate of PA [97].

Additional research examining well-established correlates of PA in youth (e.g., parental support, self-efficacy, and physical environment factors) is needed in countries experiencing rapid socioeconomic and environmental changes [30, 80, 97].

A large proportion of mothers and children engaged in high levels of sedentary behavior. More than half of the children in our study reported ≥2 hrs/day of sedentary behavior in the 2000 and 2004 cohorts, mostly from TV/DVD watching. Our finding suggests a trend toward increased sedentary behavior among Chinese youth, since previous CHNS research found only 8% of Chinese youth (6-18 years) watched TV ≥2 hrs/day in 1997 [55]. Increased sedentary behavior in children and mothers is correlated with greater TV ownership in Chinese households [45]. Household TV ownership in China increased from 63% in 1989 to more than 95% in 2004. In 2006, 98% of Chinese households with children had a color TV [49]. High sedentary behavior, namely hours of TV watching, has been linked to detrimental health implications in children and adults (e.g., greater body mass index, increased cardiovascular disease risk) [98-100]. These negative health implications also pose a potentially large economic burden [101], thus targeted public health policy and interventions aimed at limiting sedentary behavior in the Chinese population are critical.

There are some study limitations that necessitate explanation. First, self-reported PA data is subject to recall and social desirability biases. While social desirability bias has been associated with an over-estimation of PA in more developed countries [102, 103], less is known about the potential for social desirability bias in developing countries where the benefit of PA and stigma of overweight is less widespread. A second limitation is the inability of the MET-hrs/wk measurement to consider individual differences in energy expenditure associated with the same activities. However, the use of the MET remains the most appropriate means for estimating energy costs associated with self-reported physical activities [104] and our application of adult and youth compendiums ensures the most accurate comparison of mother and child PA patterns. Our inclusion criteria and cohort determination resulted in a smaller sample population, which may have limited our ability to detect cohort or additional socioeconomic effects on PA/inactivity patterns. Lastly, our 2-4 year time frame was a relatively short period of time to observe PA changes.

Our study was unique in longitudinally comparing PA patterns of mothers versus children over time. A major strength of the CHNS is use of the same data collection tools for the assessment of PA in mothers and children, and our use of adult and child compendiums provided examination of PA measures in mothers versus children with improved accuracy. While previous CHNS investigators have separately studied PA patterns and their relationship with urbanization or socioeconomic factors in adults and children [54, 55, 76, 77], our study was the first to systematically compare parent-child PA patterns and to investigate how PA evolves over periods of rapid socioeconomic growth in China.

Continued emphasis on PA promotion among Chinese youth is needed to further increase and maintain child PA as they age, while concerted efforts to improve PA among Chinese adults are also necessary. Additional initiatives to prevent further increases and reduce existing levels of sedentary behavior in mothers and children are crucial. Focusing PA promotion at the family-level could increase the public health impact and effectiveness of these interventions [105-107].

The success of these efforts will continue to be challenged by rapid urbanization, technological advances, and socioeconomic development, so PA policy and interventions must be cognizant of how these factors influence PA and inactivity patterns. Future research integrating PA and dietary intake patterns is needed to better understand how these patterns relate to overweight and obesity in adults versus children.

Table 5.1. Baseline characteristics of mother-child pairs by cohort. China Health and Nutrition Survey.[1,2]

	2000 Cohort	2004 Cohort
Survey years	2000, 2004	2004, 2006
N	167	186
Child's gender, *% male*	55.7	51.1
Child's age, *y**	7.4 ± 0.9	8.4 ± 0.9
Mother's age, *y**	32.8 ± 3.5	34.6 ± 3.8
Mother's education, *%*		
None/primary school	52.5	42.5
Middle school	34.4	41.3
High school	8.7	8.4
College, technical or higher	4.4	7.8
Annual household income, *yuan*[3*]	16045 ± 14267	20740 ± 18733
Household residence, *% rural*	76.7	76.3

[1]Values are mean ± SD or percentage.
[2]Data were missing for mother's age (n=11), mother's education (n=14), and household income (n=10).
[3]Annual household income inflated to 2006 yuan currency values.
*Different between cohorts, *P*<0.001.

Table 5.2 MET-hrs/wk for total and categories of commuting, leisure-time sports, and sedentary behaviors and average annual changes in mothers and children by cohort. China Health and Nutrition Survey.[1]

	2000 Cohort (Baseline 2000; Follow-up 2004)						2004 Cohort (Baseline 2004; Follow-up 2006)					
	Children			Mothers			Children			Mothers		
	Baseline	Follow-up	Annual change	Baseline	Follow-up	Annual change	Baseline	Follow-up	Annual change	Baseline	Follow-up	Annual change
Total commuting[2]	6.5 (9.8)*	8.6 (11.5)	0.5	7.2 (8.3)*	5.9 (12.3)	-0.3	8.2 (10.9)*	8.5 (8.6)	0.2	7.1 (15.2)*	5.0 (7.7)	-1.1
Walking	6.0 (8.6)*	5.6 (11.1)		4.5 (5.9)*	3.5 (5.7)		6.2 (10.7)*	5.9 (6.6)		3.9 (10.1)*	3.3 (5.2)	
Biking	0.7 (5.8)*	3.1 (6.4)		3.3 (5.6)*	3.2 (13.3)		2.1 (5.7)*	2.6 (7.7)		4.3 (13.6)*	2.1 (6.0)	
Total leisure-time sports[2]	7.5 (17.9)†	21.1 (48.2)	3.4	1.8 (9.6)*	2.2 (14.4)	0.1	10.6 (31.2)	14.7 (33.2)	2.1	2.2 (11.9)*	3.2 (11.1)	0.5
Gymnastics	0.5 (2.5)*	1.2 (9.4)		<0.1 (0.4)*	0.8 (8.3)		1.4 (6.7)*	1.7 (7.7)		0.4 (5.0)*	0.7 (6.5)	
Track, swimming	4.5 (14.7)*	8.3 (26.7)		0.3 (3.1)*	0.2 (2.3)		5.0 (23.6)*	4.4 (15.2)		1.0 (8.4)*	1.0 (5.7)	
Ball sports	1.5 (7.6)*	8.8 (22.5)		0.2 (1.7)*	0.9 (8.8)		3.1 (15.0)*	6.7 (20.9)		0.7 (7.0)*	0.8 (4.7)	
Other sports	1.1 (3.7)*	2.8 (10.2)		1.3 (8.1)*	0.1 (1.8)		1.1 (6.0)*	2.0 (7.2)		0.1 (1.4)*	0.5 (4.1)	
Sedentary[2]		21.4 (18.2)			15.5 (12.6)			22.6 (11.6)			15.3 (10.5)	
TV/DVD watching		12.7 (10.8)			13.3 (9.4)			14.4 (8.9)			12.8 (8.2)	
Board/video games		3.4 (8.2)			0.1 (1.4)			2.2 (4.2)			0.0 (0.0)	
Reading/writing		4.5 (5.2)			1.7 (4.8)			5.0 (5.2)			1.3 (3.7)	
Computer usage		0.8 (3.3)			0.4 (2.4)			1.0 (3.6)			1.3 (5.4)	
Homework[3]		13.3 (11.7)						3.5 (9.9)				

[1]Values are means (SD).
[2]Categories of commuting, leisure-time sports, and sedentary behaviors do not sum to the total MET-hrs/wk, since a child or mother can report MET-hrs/wk from more than one category.
[3]Homework not included in total sedentary behavior.
*Different between baseline and follow-up, P<0.05.

Table 5.3. Proportion with high or low activity levels for commuting, leisure-time sports, and sedentary behavior for mothers and children by cohort. China Health and Nutrition Survey[1]

	2000 Cohort (Baseline 2000; Follow-up 2004)				2004 Cohort (Baseline 2004; Follow-up 2006)			
	Children		Mothers		Children		Mothers	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
Commuting[2]								
Low activity	94.0	88.0	78.4	89.3	89.8	86.0	83.3	88.2
High activity	6.0	12.0	21.6	10.2	10.2	14.0	16.7	11.8
Leisure-time sports[3]								
Low activity	90.8	79.1	88.3	96.3	88.4	81.8	95.6	91.2
High activity	9.2	20.9	11.7	3.7	11.6	18.2	4.4	8.8
Sedentary[4]								
Low sedentary behavior		41.1		71.2		50.8		71.8
High sedentary behavior		58.9		28.8		49.2		28.2

[1]Values are percentages.
[2]Low commuting activity = MET-hrs/wk equivalent of <30 minutes/day of biking/walking; high commuting activity = MET-hrs/wk equivalent of $\geq$30 minutes/day of biking/walking.
[3]Low leisure-time sports = mother or child does not meet the WHO Global PA Recommendation; high leisure-time sports activity = mother or child meets theWHO Global PA Recommendations.
[4]Low sedentary behavior = MET-hrs/wk equivalent of <2 hrs/day of sedentary behavior; high sedentary behavior = MET-hrs/wk equivalent of $\geq$2 hrs/day of sedentary behavior.

Table 5.4. Mother-child associations for high commuting, leisure-time sports or sedentary behaviors at baseline and follow-up. China Health and Nutrition Survey[1,2]

	Outcome: high activity/behavior in children for corresponding activity/behavior category	
Maternal exposure	Baseline	Follow-up
Commuting		
Low activity	1.00	1.00
High activity	2.72 (1.08, 6.87)‡	3.13 (1.37, 7.16)†
Leisure-time sports		
Low activity	1.00	1.00
High activity	3.61 (1.14, 11.41)‡	0.87 (0.26, 2.93)
Sedentary		
Low sedentary behavior	*	1.00
High sedentary behavior	*	0.58 (0.35, 0.97)‡

[1]Separate models for each outcome variable (child commuting, leisure-time sports, and sedentary).
[2]Odds Ratio (95% CI) controlled for child's gender, child and maternal age, maternal education, residence, income, and cohort.
†*P*<0.01, ‡*P*<0.05
*Sedentary behavior available at follow-up only for mothers.

Table 5.5. Cross-sectional examination of socioeconomic correlates of high commuting, leisure-time sports, and sedentary behaviors in mothers and children. China Health and Nutrition Survey[1,2,3]

	Outcome: high level commuting activity		Outcome: high level sports activity		Outcome: high level sedentary behavior	
Exposure	Children	Mothers	Children	Mothers	Children	Mothers
Household residence						
Urban	1.00	1.00	1.00	1.00	1.00	1.00
Rural	0.43 (0.25, 0.75)[†]	0.74 (0.45, 1.24)	0.97 (0.57, 1.66)	0.67 (0.33, 1.35)	0.64 (0.37, 1.12)	0.63 (0.35, 1.13)
Household income						
Low	1.00	1.00	1.00	1.00	1.00	1.00
Middle	1.30 (0.66, 2.54)	0.90 (0.52, 1.56)	1.55 (0.83, 2.89)	0.70 (0.29, 1.69)	0.87 (0.48, 1.59)	0.86 (0.43, 1.45)
High	0.81 (0.39, 1.68)	0.83 (0.47, 1.47)	1.53 (0.82, 2.88)	0.58 (0.23, 1.46)	0.86 (0.47, 1.58)	1.20 (0.61, 1.46)
Maternal education						
None/primary	1.00	1.00	1.00	1.00	1.00	1.00
Middle school	1.52 (0.85, 2.71)	0.86 (0.53, 1.39)	1.57 (0.94, 2.60)	0.82 (0.35, 1.91)	0.71 (0.43, 1.19)	1.17 (0.66, 2.09)
High school	1.06 (0.39, 2.89)	0.68 (0.28, 1.64)	1.54 (0.69, 3.43)	3.32 (1.21, 9.19)[‡]	0.45 (0.19, 1.07)	1.24 (0.49, 3.16)
Technical, college or higher	1.37 (0.49, 3.85)	0.51 (0.17, 1.55)	1.40 (0.55, 3.61)	9.34 (3.56, 24.63)[‡]	0.56 (0.21, 1.50)	4.45 (1.61, 12.30)[†]

[1]Odds Ratio (95% CI).

[2]Separate models for mothers and children for each outcome variable (high commuting, leisure-time sports, and sedentary). Child models controlled for cohort, child's age and gender. Maternal models controlled for cohort and maternal age.

[3]Models for commuting and leisure-time sports activities used data from both measurement occasions, and models for sedentary behavior used data at follow-up.

[†]$P<0.01$, [‡]$P<0.05$

VI. Comparison of dietary and activity correlates of body mass index in Chinese mothers and children

A. Introduction

Global research reveals important differences regarding the onset and progression of overweight prevalence and trends for adults and children [41]. The onset of increased overweight in adults precedes that found in children, with initial overweight prevalence values 2-8 times greater in adults versus children (e.g., overweight prevalence of 13% in Chinese adults versus 5% in Chinese children in 1991) [41]. Annual increases in overweight were also greater in adults versus children in newly industrialized and developing countries, resulting in a greater proportion of adults versus children becoming overweight each year. Despite the initial lag in the onset and progression of child overweight, additional evidence suggests that this gap between adults and children is closing as child overweight trends accelerate [41].

These varying levels and trends in adults versus children are characteristic of the overweight epidemic in the Chinese population. Chinese adults precede children in the onset of increased overweight, and average annual increases in overweight from 1991 to 2004 were more than two times greater in adults versus children [41, 67]. These differences are hypothesized to be influenced by biological differences in adults and children, variations in how adults and children are affected by environmental change, and differences in the interaction between biological and environmental factors [41]. More research is needed to better understand the effect of environmental changes, namely if rapid changes in the nutrition and PA environment differentially influence adult-child dietary and PA behaviors and their associations with BMI.

Existing literature comparing dietary, PA and BMI dynamics in adults versus children has primarily focused on the parent-child relationship [11, 34-38, 40, 97]. Positive correlations between parent and child BMI have been shown to emerge at age 7; a dose-response relationship has been shown between childhood overweight and the number of overweight parents [34, 36, 38]. However, the majority of this research has been conducted in developed countries, and less is known about parent-child associations in developing countries experiencing increases in overweight and obesity. While one cross-sectional study conducted in urban and rural regions of Beijing found positive parent-child associations for obesity [108], more research is needed to explore longitudinal parent-child associations for BMI and overweight within the context of a rapidly changing nutrition and PA environment.

Dietary and PA correlates of overweight are well-documented in adults and children [42-44]. Body fatness has been shown to be positively associated with dietary variety and frequency of restaurant food consumption and negatively associated with physical activity level in Chinese urban adults [69]. However, examination into the relationships between increased BMI with dietary and activity behaviors in mothers versus children has not been done. Using data from the China Health and Nutrition Survey (CHNS), we investigated these relationships and mother-child BMI associations in 2 separate cohorts of mother-child pairs followed over a 2-4 year time period. The primary study objectives were (1) to examine the relationships between mother and child BMI z-score or overweight with increasing child age; (2) to examine how dietary and PA behaviors relate to BMI z-score in mothers versus children.

B. Methods

1. Data and Subjects

The CHNS began in 1989 with subsequent surveys every 2-4 years. A multistage, randomized cluster design was utilized to survey around 4,400 households and roughly 19,000 individuals from 9 Chinese provinces that vary in geography, socioeconomic growth, and health indicators. The study met the standards for the ethical treatment of participants and was approved by the Institutional Review Boards of UNC and the Institute of Nutrition and Food Safety.

Our study sample included 2 separate cohorts of biological mother-child pairs followed over a 2 or 4-year time period (2000 Cohort: 2 measurement occasions 2000 & 2004; 2004 Cohort: 2 measurement occasions 2004 & 2006). Our use of the 2 cohorts was an extension of previous research that examined dietary and physical activity behaviors in these cohorts. Inclusion criteria were complete dietary, PA, height, weight, and age data for mothers and children at both measurement occasions, resulting in a study sample of 269 mother-child pairs. Since data on sedentary behavior in adults was first collected in the 2004 CHNS, only cross-sectional examination of the relationship between sedentary behavior and BMI outcome was possible.

2. Measures

CHNS administered structured questionnaires to all household members. Parents or primary caregivers completed or assisted with the completion of surveys for children <10 years. Details concerning the socioeconomic measures (i.e., residence, income, maternal education) have been previously published [49, 67]. Trained field staff directly measured height and weight in survey participants. Height was measured without shoes to the nearest 0.2 cm by using a portable stadiometer. Weight was measured to the nearest 0.1 kg using a calibrated beam scale with participants wearing light clothing and no shoes.

BMI was determined by dividing weight by height squared (kg/m^2). Maternal overweight was defined as BMI $\geq$25 kg/m^2 using the WHO Standards. Child overweight was determined using the International Obesity Task Force (IOTF) BMI-for-age reference [109]. BMI z-scores for mothers and children were determined using the 2000 NCHS reference standards. The 2000 NCHS reference standard for females, age 20 years, was used to determine BMI z-scores for mothers. This approach for BMI z-score determination has been done in previous research comparing BMI differences in children and adults [110-112].

PA data included questions on participation and weekly time spent in commuting to and from school or work and in specific groups of leisure-time sports activities and sedentary behaviors. Given that our research was focused on comparable mother-child variables, in-school sports and occupational PA were included as control variables for children and mothers, respectively. Total metabolic equivalent hours per week (MET-hrs/wk) from each PA domain were determined using the Compendium of Energy Expenditures for Youth for children and the Compendium of PA for mothers [32, 33]. Additional details on PA measures are available in previous publications [113].

High versus low activity categories based on the World Health Organization's Global PA Recommendations or on time-based cut-points were created to facilitate interpretation of the findings and applicability to PA research, policy, and intervention efforts [87]. High commuting activity was defined as the MET-hrs/wk equivalent of $\geq$30 minutes/day of biking or walking. High leisure-time sports activity for mothers or children was defined as meeting WHO's Global PA Recommendations. High leisure-time sports activity for children was defined as the MET-hrs/wk equivalent of at least 60 minutes of moderate- to vigorous-intensity PA daily, with vigorous-intensity PA at least 3 times per week [87]. High leisure-time sports activity for mothers was defined as the MET-hrs/wk equivalent of at least 150 minutes of moderate-intensity PA per week, at least 75 minutes of vigorous-intensity PA per week, or an equivalent combination of moderate- to vigorous-intensity PA [87]. Sedentary behavior was categorized into MET-hrs equivalents of <1, 1-2, 2-3 or $\geq$3 hours/day of sedentary behavior to ease interpretation and for comparison with other similar research [98, 100, 114, 115].

Dietary data included household food consumption data and 3 consecutive 24-hour recalls, with data collection randomly allocated during the week. Chinese Food Composition Tables were used to determine nutrient values from dietary data; mean daily energy intake values were determined using 3 days of dietary information. Dietary variables were the percentages of total energy (% E) from animal-source foods (ASF), fats/oils, and grains.

Additional details on the dietary variables are available in previous publications [113]. The dietary variables were dichotomized into high versus low categories based on the following cut-points: high ASF = $\geq$10% of total energy intake from ASF; high fats/oils = $\geq$30% of total energy intake from fats/oils; low grains = <70% of total energy intake from grains.

3. Statistical Analysis

All analyses were conducted using Stata version 11.0 (Stata Corporation, College Station, TX, USA). To examine associations between mother and child BMI z-scores, we used Pearson correlation coefficients. Mother-child correlations were examined at baseline and follow-up and adjusted for cohort, socioeconomic variables (i.e., maternal education, residence, income), and maternal and child age. To examine mother-child associations for overweight, we used logistic regression models. Separate logistic regression models were conducted at baseline and follow-up, and models controlled for cohort, socioeconomic variables, and maternal and child age.

To examine cross-sectional associations between BMI z-score with dietary and PA behaviors in mothers versus children, we used linear and seemingly unrelated regression (SUR) models. Separate linear regression models were conducted in mothers and children (male and female) using follow-up data from both cohorts. SUR models enabled testing of the equality of the coefficients in mother and child equations with consideration of correlated error terms. Our models are focused on comparing associations between dietary and PA behaviors and BMI z-score in mothers versus children and do not address causality. Examination of the causal relationship between diet and activity behaviors and BMI in mothers versus children would require corrections for endogeneity. We developed a directed acyclic graph (DAG) to guide our analysis and qualitatively understand the relations among covariates, dietary and PA exposures, and BMI z-score [88]. Socioeconomic and cohort variables, maternal and child age, domestic activity, and in-school or occupational activity were included as confounders based on our DAG as well as supporting research [48, 54, 67, 76, 97, 116].

To examine associations between annual change in BMI z-score with dietary and PA patterns in mothers versus children, we used linear regression and SUR models. Separate linear regression models were conducted in mothers and children (male and female) using baseline and follow-up data from both cohorts. The equality of mother and child coefficients was tested using SUR models. All models were adjusted for cohort.

C. Results

1. Descriptive

Baseline characteristics of the 2 cohorts are shown in Table 6.1. Significant differences between the cohorts were found for child's age, mother's age, and annual household income (P<0.05). No significant differences between the cohorts were found for child's gender, maternal education, and household residence.

2. Mother-child associations for BMI z-score or overweight

Positive mother-child correlations for BMI z-score were found at baseline and follow-up (P<0.001) (Table 6.2). Mother-daughter BMI z-score correlations were stronger than mother-son correlations. A positive mother-child relationship was also found for overweight status (Table 6.3). At follow-up, children with overweight mothers were more likely to be overweight compared to children with mothers who were not overweight (OR: 2.41; 95% CI: 1.04, 5.59). This relationship did not differ by child's gender.

3. Modeling cross-sectional associations between BMI z-score with dietary, PA, and sedentary behaviors in mothers and children

Sedentary behavior was positively associated with BMI z-score in mothers (P<0.05) (Table 6.4). Sedentary behavior $\geq$ 3 hrs/d was associated with a higher BMI z-score of 0.46 (CI: 0.07, 0.84) in mothers, while no relationship between sedentary behavior and BMI z-score was found for male or female children. Results from SUR models indicated that the coefficients for sedentary behavior in mothers were not significantly different than the coefficients for sedentary behavior in male or female children. No relationships between BMI z-score with leisure-time sports or commuting activities were found in mothers or children. The % E from ASF, fats/oils, or grains variables were not significantly associated with increased BMI z-score in mothers or children and did not significantly differ in mothers versus male or female children.

D. Discussion

Our study was unique in examining the longitudinal relationship between mother and child BMI and in investigating associations between BMI z-score with dietary and activity behaviors in mothers versus children. We found positive mother-child BMI z-score correlations at baseline and follow-up and an increased likelihood of childhood overweight in children with overweight mothers at follow-up. High sedentary behavior was associated with a higher BMI z-score in mothers, but no associations between BMI z-score and sedentary or physical activities were found in children. Dietary correlates of increased BMI in mothers versus children were less conclusive.

Positive mother-child associations for BMI z-score and overweight were found. Mother-child BMI z-score correlations at baseline and follow-up ranged from 0.18 to 0.31, which is consistent with research conducted in developed countries showing mother-child BMI correlations ranging from 0.20 to 0.33 in children <10 years of age [34-36, 117]. Furthermore, an elevated odds ratio (OR) for childhood overweight associated with maternal overweight is also consistent with previous studies showing higher OR for child overweight with at least one overweight parent [35, 40, 118, 119]. Our findings suggest that significant mother-child associations for BMI and overweight persist across developed and newly industrialized country settings.

The positive relationship between high sedentary behavior and increased BMI z-score in mothers found is well-supported by past studies documenting positive relationships between television viewing and obesity in women [98, 100, 114-116,120-124]. These studies found that increased television viewing was associated with a 23% increase in obesity and was positively associated with BMI, independent of diet and exercise [120-124]. The positive association between sedentary behavior and BMI z-score found in our study is problematic for the health of Chinese women given recent declines in occupational and domestic activities and minimal leisure-time sports activity [76]. Therefore, public health initiatives focused at reducing television viewing and other sedentary behaviors are critical for obesity prevention.

There are some study limitations that need to be addressed. First, our relatively small analytic sample may have limited our ability to detect associations between BMI and diet or PA behavior correlates. Secondly, further exploration of additional dietary measures, such as dietary patterns, may provide added insight. More energy-dense, low-fiber dietary patterns have been significantly linked with increased BMI in adults and children [125-127]. A final limitation pertains to our study of sedentary and PA behavior correlates of increased BMI. We examined the relationship between BMI z-score with sedentary and physical activity behaviors in mothers and children in separate PA domains (i.e., commuting, leisure-time sports and sedentary behaviors). While our study found a significant association between BMI z-score and sedentary behavior in mothers, grouping mothers and children into mutually exclusive clusters that incorporated all PA domains may have yielded additional insight. Previous research in Chinese youth using cluster analysis found significant associations between physical activity/inactivity clusters and overweight that were not detected using more traditional models [128].

Our study provided a novel look at mother-child relationships for BMI and overweight within a newly industrialized country setting. We were also first to systematically examine associations between increased BMI with dietary and PA behaviors in mothers versus children. Our findings revealed significant mother-child BMI associations and significant sedentary behavior-BMI relationships in mothers that are consistent with those found in developed countries. Improved understanding of PA and dietary behavior correlates of increased BMI is needed to more thoroughly evaluate differences in the onset and progression of overweight in adults versus children. Despite the need for additional research, overweight prevention efforts in China must consider the mother-child overweight relationship and focus on reducing sedentary behavior and promoting leisure-time sports in mothers and children.

Table 6.1. Baseline characteristics of mother-child pairs by cohort. China Health and Nutrition Survey.[1,2]

	2000 Cohort	2004 Cohort
Survey years	2000, 2004	2004, 2006
N	128	141
Child's gender, % male	55.4 (49.3, 61.6)	51.8 (45.9, 57.6)
Child's age, y*	7.4 $\pm$ 0.8	8.4 $\pm$ 0.8
Child overweight prevalence, %	7.0%	12.1%
Mother's age, y*	32.7 $\pm$ 3.3	34.6 $\pm$ 3.7
Maternal overweight prevalence, %	14.1%	18.4%
Mother's education, %		
None/primary school	51.5 (45.3, 57.7)	42.8 (36.1, 47.6)
Middle school	33.6 (27.8, 39.4)	37.0 (30.5, 41.8)
High school	9.4 (5.8, 13.0)	10.9 (7.0, 14.2)
College, technical or higher	5.5 (2.7, 8.3)	9.4 (5.9, 12.9)
Annual household income, yuan[3*]	15517 $\pm$ 12880	21967 $\pm$ 19588
Household residence, % rural	75.8 (70.5, 81.1)	74.5 (69.3, 79.6)

[1]Values are mean $\pm$ SD or percentage (CI).
[2]Data were missing for mother's education (n=3), and household income (n=8).
[3]Annual household income inflated to 2006 yuan currency values.
*Different between cohorts, P<0.001.

Table 6.2. BMI z-score correlations between mothers and children at baseline and follow-up. China Health and Nutrition Survey.[1]

	Measurement occasion	
	Baseline	Follow-up
Mother-child pairs[2]	0.24*	0.24*
Mother-son pairs[3]	0.22†	0.18‡
Mother-daughter pairs[3]	0.29†	0.31*

[1]Pearson correlations of BMI z-scores in children and mothers.
[2]Adjusted for cohort, residence, income, maternal education, child's gender and maternal and child age.
[3]Adjusted for cohort, residence, income, maternal education, and maternal and child age.
*P<0.001, †P<0.01, ‡P<0.05.

Table 6.3. Odds Ratios for overweight in children based on maternal overweight. China Health and Nutrition Survey.[1]

	OR for overweight in children	
Maternal exposure	Baseline	Follow-up
Mother-child pairs[2]		
Mother not overweight	1.0	1.0
Mother overweight	2.11 (0.74, 6.03)	2.41 (1.04, 5.59)*
Mother-son pairs[3]		
Mother not overweight	1.0	1.0
Mother overweight	1.66 (0.25, 11.07)	2.70 (0.78, 9.39)
Mother-daughter pairs[3]		
Mother not overweight	1.0	1.0
Mother overweight	2.00 (0.44, 9.13)	2.23 (0.64, 7.76)

[1]Odds ratios (95% CI) used data from both cohorts.
[2]Adjusted for cohort, residence, income, maternal education, child's gender, and maternal and child age.
[3]Adjusted for cohort, residence, income, maternal education, and maternal and child age.
*P<0.05

Table 6.4. Cross-sectional examination of BMI z-scores and dietary and activity behaviors in mothers and children. China Health and Nutrition Survey.[1,2,3]

	Outcome: Child BMI z-score		Outcome: Mother BMI z-score
Exposure	Males	Females	
Sedentary behavior[4]			
<1 hr/d	Ref	Ref	Ref
1-2 hrs/d	-0.07 (-1.01, 0.86)	0.09 (-0.72, 0.89)	0.19 (-0.08, 0.45)
2-3 hrs/d	-0.46 (-1.37, 0.46)	-0.07 (-0.89, 0.75)	0.06 (-0.25, 0.37)
≥3 hrs/d	-0.35 (-1.26, 0.57)	0.29 (-0.53, 1.11)	0.46 (0.07, 0.84)*
Leisure-time sports[5]			
Low level	Ref	Ref	Ref
High level	-0.01 (-0.55, 0.56)	0.69 (-0.11, 1.49)	-0.01 (-0.41, 0.40)
Commuting activity[6]			
Low level	Ref		Ref
High level	-0.40 (-1.23, 0.44)	-0.02 (-0.78, 0.74)	-0.04 (-0.40, 0.33)
% E from ASF			
<10% from ASF	Ref	Ref	Ref
≥10% from ASF	0.18 (-0.31, 0.66)	0.30 (-0.25, 0.87)	-0.01 (-0.25, 0.22)
% E from grains			
≥70% from ASF	Ref	Ref	Ref
<70% from ASF	0.12 (-0.47, 0.70)	0.06 (-0.77, 0.90)	-0.17 (-0.45, 0.11)
% E from fats/oils			
<30% from fats/oils	Ref	Ref	Ref
≥30% from fats/oils	1.06 (-0.24, 2.37)	0.19 (-1.44, 1.83)	0.26 (-0.24, 0.75)

[1]Values are coefficients (95%CI).
[2]Separate linear regression models for mothers and children by gender used follow-up data from both cohorts. Child models controlled for cohort, in-school activity, residence, income, child's gender, age and energy intake (kcals). Models for mothers controlled for cohort, occupational and domestic activities, residence, income, maternal education, maternal age, and mother's energy intake (kcals).
[3]Child and Maternal BMI z-scores determined using 2000 NCHS Growth charts.
[5]Sedentary behavior categories defined as the MET-hrs equivalent of <1, 1-2, 2-3 or ≥3 hrs/d of sedentary behavior.
[6]Low leisure-time sports=mother/child does not meet WHO PA Recommendations; high leisure-time sports activity=mother/child meets WHO PA Recommendations.
[7]Low commuting activity=MET-hrs equivalent of <30 min/d of biking or walking; high commuting activity=MET-hrs equivalent of ≥30 min/d of biking or walking.
*P<0.05.

VII. Synthesis

A. Overview of findings

Our research aimed to better understand dietary and PA behaviors and their relationships with BMI in mothers versus children within a changing nutrition and PA environment. Using longitudinal data from the China Health and Nutrition Survey, we conducted longitudinal, cross-cohort comparisons of dietary and PA behaviors in mothers versus children and investigated how these behaviors relate to BMI in mothers and children. Particular emphasis was placed on examination of mother and child dietary and PA patterns by income, residence, and maternal education differentials to enable study of how mother and child dietary and PA patterns change in a newly industrialized country experiencing rapid socioeconomic development. Furthermore, our study of mother-child associations for dietary, PA, and BMI patterns fills important gaps in the literature, given previous research on these associations has primarily been conducted in developed countries.

We found that mothers and children experienced shifts toward a diet higher in ASF and lower in grains, which is an expected consequence of a rapidly changing nutrition environment where more Westernized foods are increasingly available, accessible and affordable. We also documented a cohort difference, with mothers and children in the later versus earlier cohorts consuming a less traditional Chinese diet. Probable contributors to this cohort difference include rapid growth of supermarkets, greater household TV ownership, and increasing presence of the Western media in the mid- to late 1990s. While children were earlier adopters and maintainers of a less traditional Chinese diet, mothers experienced more pronounced shifts toward a less traditional diet with increasing child age.

More pronounced dietary shifts in mothers versus children were notable, but examination of dietary correlates of increased BMI in mothers versus children was less conclusive. Further exploration of additional dietary measures, such as dietary patterns, may provide added insight. More energy-dense, low-fiber dietary patterns have been significantly linked with increased BMI in adults and children [126, 127], thus further investigation into the relationship between unhealthy dietary patterns and increased BMI in mothers and children within newly industrialized country settings is needed.

PA trends in mothers versus children were dissimilar. Children reported temporal increases in commuting and leisure-time sports activities, whereas mothers reported declines in commuting activity and little change in leisure-time sports activity over time. High sedentary behavior (i.e., $\geq$3 hours/day) was associated with a higher BMI z-score in mothers. The lack of associations between lower BMI z-scores with high leisure-time sports or commuting activities in mothers and children may be due to the smaller sample size and limited number of mothers and children participating in high leisure-time sports. While our study sought to examine comparable mother-child PA behaviors, extending our research to include other PA domains (e.g., occupational and in-school PA) is needed. Previous research has shown significant associations between increased occupational activity and decreased body weight in Chinese women [54], thus inclusion of all PA domains is important to obtain a more complete understanding of the activity-BMI relationship. Furthermore, use of additional methods such as cluster analysis categorizing PA data from all domains into different activity patterns would yield additional insight into the PA-BMI relationship in mothers versus children.

Our study provided an initial look into how mother-child dietary and activity behaviors vary over time and across different time periods and examined how these behaviors relate to BMI in mothers versus children. While dietary findings were less conclusive, PA findings documented significant PA-BMI associations in mothers. Despite variations in dietary and PA behaviors for mothers and children, we also found significant mother-child associations between dietary, PA, and BMI patterns over time. Moderate to strong mother-child correlations were found for the dietary variables. We also documented a significant mother-child relationship for high leisure-time sports activity at baseline but no association at follow-up, which is consistent with previous research showing decreased mother-child associations for sports with increasing child age. Additionally, positive mother-child associations for BMI z-score and overweight were similar to those found in developed countries. Our findings support nutrition policy and intervention efforts targeted at the family level and emphasize the need for continued research using an expanded set of dietary and PA measures and additional methodologies to better understand the complex relationships between dietary and activity behaviors and BMI in adults and children.

B. Limitations and Strengths

There are some study limitations that necessitate explanation. First, there is the potential for inaccurate dietary or PA assessment given that CHNS dietary and PA data is self-reported. While past research on the CHNS dietary assessment approach found only a small degree of underreporting (8%) by women [69], less is known about variations in levels of underreporting by weight status classification in the Chinese population. Accurate dietary assessment may also be challenged by measurement error and recall bias, although quality control procedures incorporated into the CHNS data collection process help address these challenges (i.e., individual 24-hour dietary recalls were cross-checked with household food consumption data; households were revisited if discrepancies were found). Accurate PA assessment is subject to recall and social desirability biases. While social desirability bias has been associated with an over-estimation of PA in more developed countries [102, 103], less is known about the potential for social desirability bias in newly industrialized and developing countries where the benefit of PA and stigma of overweight is less widespread.

Additional study limitations pertain to study design and methodological issues. Our longitudinal, cross-cohort study design resulted in a relatively small sample population, which may have limited our ability to detect associations between BMI and dietary or PA correlates. Furthermore, our focus on only comparable mother-child dietary and PA behaviors and separate examination of their relationships with increased BMI may have limited our comprehension of dietary and PA correlates of BMI in mothers versus children. A more integrated approach, such as cluster analysis using data from dietary patterns and from all PA domains, would yield important insight into how lifestyle patterns relate to BMI in adults and children.

Despite these limitations, our study has several strengths. The extensive nature of the CHNS data and use of the same dietary and PA assessment methods in mothers and children permitted more accurate, longitudinal examination of mother-child dietary and PA behaviors. Our selection of relative dietary intake measures expanded upon existing dietary research in China, enabled mother-child comparability, and allowed examination of dietary shifts characterizing a less traditional Chinese diet. Our application of adult and youth compendiums for the assignment of MET values contributed to the examination of PA measures in mothers versus children with improved accuracy. Lastly, our use of multiple cohorts resulted in improved understanding into how mother and child dietary and PA behaviors evolve over periods of rapid socioeconomic growth in China.

Our study was first to systematically examine the relative influence of dietary and PA behavior correlates to increased BMI in mothers versus children within a newly industrialized country setting. While we encountered challenges in our examination of the diet-BMI relationship, our PA findings were consistent with significant PA-BMI relationships in women documented in developed countries. Our research presented an important first look into how dietary and PA behaviors relate to BMI in mothers and children. Knowledge gained from our study can be used to better inform and guide future research examining relationships between dietary and PA behaviors and BMI in adults and children.

C. Conclusions

Our study comprehensively and systematically compared dietary, PA, and BMI dynamics in mothers versus children over time and across different time periods in a country experiencing rapid socioeconomic growth. Our findings resulted in improved understanding into how dietary and PA behaviors are changing in mothers and children over time and how these changes are related to BMI. Significant mother-child associations for dietary, PA, and BMI patterns support the need for dietary interventions and PA promotion efforts to be centered at the family-level. Future research using an expanded set of dietary and PA measures and methods that capture lifestyle patterns would provide additional insight into dietary, PA, and BMI relationships in mothers versus children. Extension of this research into other newly industrialized and developing countries is also needed to better explain global differences in overweight prevalence and trends in adults versus children.

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