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The Impacts of Grandparental Caregiving on Early Childhood Obesity in China

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The Impacts of Grandparental Caregiving on Early Childhood Obesity in China

A thesis submitted in partial satisfaction of the requirements for

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by

Linghui Jiang

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ABSTRACT OF THE THESIS

The Impacts of Grandparental Caregiving on Early Childhood Obesity in China

by

Linghui Jiang

Master of Science in Community Health Sciences

University of California, Los Angeles, 2015

Professor Deborah C. Glik, Chair

The prevalence of early childhood obesity is increasing rapidly in China. Grandparents have been blamed by public media for facilitating the trend through overfeeding and spoiling their grandchildren. However, researches are scarce on the role of grandparental caregiving in obesity among preschoolers. This empirical study aimed to assess the impacts of grandparental caregiving on obesity among children aged 0-5 years taking into consideration other contextual factors such as family socioeconomic status and neighborhood environment.

Drawn data of 686 children aged 0-5 years old and their families from the China Health and Nutrition Survey in the year 2011, this study compared obesity-related knowledge and practices of grandparents with parents, and contrasted the prevalence of obesity and obesogenic behaviors among children in three types of family living arrangements which reflect a gradient amount/level of grandparents' involvement in caregiving: nuclear families, three-generation families and skipped-generation families.

The results showed that grandparental caregiving is not associated with increased risk of obesity among preschoolers. Compared with parents, grandparents were less aware of national nutrition guideline (18.5% vs 30.0%, $p<0.01$), had lower nutrition knowledge score (8.4 vs 8.9, $p<0.01$), and watched television longer per day (120 vs 105 mins, $p<0.01$). However, there was no difference in dietary intake among children in three types of living arrangement. The length of daily television watching was the shortest for children in three-generation families (54.4 ± 62.1mins), and the longest for children in skipped-generation family (71.8 ±76.2 minutes). Children in three-generation families, taken care of by both parents and grandparents showed significantly lower weight-for-height Z-scores than those in nuclear families, taken care of only by parent(s) ($p<0.01$). After controlling for other factors (child's age and gender, household income, education level of caregivers, enrollment in childcare, neighborhood urbanization index, and type of neighborhood) , children in three-generation families still exhibited the significant lower mean weight-for-height Z-scores than those in nuclear families and in skipped-generation families. One individual characteristic factor (child's age) and one contextual factor (type of neighborhood) were also significantly associated with child's weight-for-height Z-score.

This study concluded that grandparental caregiving does not increase the risk of obesity for preschoolers. Instead, children in the care of grandparents in three-generation families are at lower risk than those cared for only by parent(s) or only by grandparent(s). Further researches are needed to explore the mechanism or the interactions in three-generation families which form a healthier environment for preschoolers so as to inform family-oriented program planning and policy design regarding early childhood obesity prevention.

The thesis of Linghui Jiang is approved.

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INTRODUCTION

Early childhood obesity has been considered "one of the most serious public health challenges of the 21st century" (WHO, 2015a). The past decade has seen a dramatic increase in the number of overweight and obese children under five years of age worldwide, from 32 million in 2000 to 42 million in 2013 (WHO, 2014). If the trend continues, the prevalence is expected to climb globally from 7% in 2012 to 11% by 2025 (UNICEF, 2014). The rise in prevalence of childhood obesity is observed not only in affluent western countries, but also in developing countries, particularly in Africa and Asia, which have seen rapid changes in dietary and physical activity patterns during the past few decades (Popkin, 2001). The rate of increase in the prevalence of childhood obesity is 30% higher in low- and middle-income countries than in developed countries (WHO, 2015). As of 2013, eighteen million overweight children under five years old, more than two-fifths of the world's total number of overweight children, live in Asia (UNICEF, 2014).

China, which has the largest population in the world (1.35 billion), bears a very high burden of obesity and chronic diseases, due to the rapid socioeconomic development that it has experienced over the past three decades. Globally, nearly one in five overweight or obese people is Chinese (Y. Wu, 2006). The rapid increase in childhood obesity is particularly alarming in China. In 1997, only one in eight children was overweight in urban areas (Wang & Lobstein, 2006). The prevalence of overweight and obesity among Chinese children aged 7-18 years old in the coastal big cities climbed from 1.6% and 1.8% in 1985 to 23.6% and 13.6% in 2000 for males and females respectively (Ji, 2007). In 2005, the prevalence reached 32.5% for males and 17.5% for females in the northern coastal big cities (Ji & Cheng, 2008).

Obesity in early years has profound impacts on the health and wellbeing of individuals across their entire life span as well as on the health systems. Early childhood overweight not only increases the risk of obesity in adolescence and adulthood, but also increases the risk for a number of chronic conditions including type 2 diabetes, hypertension and other cardiovascular diseases (Lobstein, Baur, & Uauy, 2004; Nader et al., 2006; WHO, 2014). Health-related behaviors developed in early childhood also persist across life span. Furthermore, overweight in childhood also influences psychological development of children (Lobstein et al., 2004). Therefore, early childhood (from birth to 5 years old) has been recognized as a critical period for detecting and preventing the beginning of obesity (IOM, 2011; WHO, 2013).

Families are the most important environment in which health behaviors and development of young children are shaped by their primary caregivers. Parents are the primary social influence on pre-school child development in western countries. In contrast, extended family is the culturally preferred family form in many Asian countries. In China, the majority of adults aged 65 and above co-resides with their adult children (Zeng & Wang, 2003). As a result, grandparents are the primary caregivers for pre-school children and play an essential role in child development and health, including prevention of childhood obesity. Despite its importance, the essential role of grandparents in shaping obesity-related behaviors of preschoolers has not received adequate academic attention.

This empirical study, therefore, was to explore the association between grandparents' caregiving and early childhood obesity in China. The research questions to be answered in this study include: (1) Are grandparent caregivers different from parents in terms of their own obesity related knowledge and behaviors? (2) Does grandparents' caregiving play a positive or negative

role in preventing early childhood obesity? Does grandparents' caregiving make a difference in young children's dietary pattern and physical activities? (3) Do family socioeconomic status and neighborhood environment influence (moderate) the association between grandparent caretaking and risk of overweight/obesity among children aged 0-5 years old?

Using data from the China Health and Nutrition Survey in the year 2011, this study applied cross-sectional analysis to answer the foregoing research questions through comparing the prevalence of obesity and obesogenic behaviors among children in three different living arrangements which reflect a gradient amount/level of grandparents' involvement in caregiving: nuclear families, three-generation families and skipped-generation families. It is expected that this study will provide some insights into the complex familial and system risk factors for early childhood obesity in China so as to inform family-oriented program planning and policy design regarding early childhood obesity prevention.

LITERATURE REVIEW

This section provides an overview of previous studies pertaining to the subject matter of this study – definition of early childhood obesity, risk factors for childhood obesity, grandparental influences on childhood obesity and previous researches on early childhood obesity in China.

1. Definition of Early Childhood Obesity

Obesity are defined as "abnormal or excessive fat accumulation that presents a risk to health" (WHO, 2015b). Early childhood obesity in this research refers to overweight or obesity

among children aged from birth to five years old. However, there is no widely agreed standard for measuring early childhood obesity (Lobstein et al., 2004). Classifying overweight or obesity involves selecting: 1) an accurate measure of body fat, 2) an appropriate reference population and, 3) a suitable cut-off point (Rolland-Cachera, 2011; Wang & Lobstein, 2006). Assessing obesity in children is far more challenging than assessing adults due to their changing body fat composition with age and the complex of association between body fat and health consequences in childhood (Cole, Bellizzi, Flegal, & Dietz, 2000; Reilly, 2002).

Measuring body fat in young children is particularly difficult since many available composition measures, such as underwater weighing, air-displacement plethysmography, are not only expensive but impracticable for infants and young children (Hu, 2008). As a result, anthropometric measurements such as weight and height, and indicators derived from these measurements such as the Body Mass Index (BMI, weight/height^2) have been widely used as an indirect and easily performed indirect measurement for public health use. Previously weight-for-height was routinely used in clinical settings and chosen by many researchers and international institutions including the World Health Organization to screen overweight and obesity among children under five years of age (WHO, 1995). Recently the Body Mass Index has been increasingly accepted as a valid low-cost indirect measurement of adiposity in children for epidemiological use (Lobstein et al., 2004).

As children grow fast and their normative values of body fat composition varies with age, the anthropometric cut-offs for classifying obesity need to be adjusted for age (Rolland-Cachera, 2011). However, disagreement still exists regarding the reference population and age-based cut-offs to define early childhood obesity. Two international references, the National Center for

Health Statistics (NCHS)/WHO reference and the International Obesity Task Force (IOTF) reference (Cole et al., 2000; WHO, 1995) were commonly used. The NCHS/WHO reference was based merely on population data from the United States and classified overweight of children under five years old as >2 Z-scores of weight-for-height (WHO, 1995). This reference was questioned for the reference population from a single country and some other important technical and biological drawbacks (Mercedes de Onis & Blössner, 2003). In response to these issues, the IOTF developed new reference using internationally pooled data from six countries including Brazil, the Netherlands, the USA, the UK, Singapore, and Hong Kong of China, and defined overweight and obesity by sex between 2 and 18 years based on BMI centile curves that pass through adult BMI cut-off points of 25 and 30 kg/m^2 at age 18(Cole et al., 2000). In 2006, the World Health Organization released new child growth standards of infant and young children which is based on child growth data from a prescriptive, prospective, international sample of healthy breast-fed infants selected to represent optimum growth (WHO, 2006). These new growth charts include nine anthropometric indicators such as weight-for-height, BMI and skin-folds. The WHO recommends these new growth standards replace the old versions for assessing nutrition status among preschool children globally (Wang & Chen, 2012).

Although international references enabled comparison of epidemiological data across nations, some researchers (Lobstein et al., 2004; Reilly, 2002) have argued that a national reference point should be used for clinical screening and national epidemiological purposes since cut-offs based on national references have higher biological validity (e.g. screening sensitivity and specificity, association with measures of morbidity). Using the international reference, instead, may result in bias in estimating the prevalence of childhood obesity in some populations. For example, Asian people have higher percent body fat than westerners at the same BMI (Misra,

2003). No consensus has been achieved so far about whether international reference population or population-specific local reference should be used (Wang & Lobstein, 2006).

An ideal cut off point would be where the morbidity related to childhood obesity start to increase rapidly. This exists in theory but it has been difficult to identify markers precisely since children have less disease related to obesity than adults and the association between child obesity and morbidity could not be well correlated to locate the cut-off point (Cole et al., 2000). Therefore, the 85^{th} and 95^{th} percentile BMI-for-age cut off points for overweight and obesity for clinical use were often criticized as arbitrary as they are not as clearly correlated with increased health risks as the cut-offs for adults (Cole et al., 2000). The other BMI cut-offs developed by IOTF using BMI centile curves that pass through BMI cut-off points of 25 and 30 at age 18 were also criticized as a convenient extrapolation from adult BMI cut-offs (Reilly, 2002).

2. Risk Factors for Early Childhood Overweight

Causes of early childhood overweight are complex and multi-faceted, and include genetic, environmental and social factors (Formisano et al., 2014). Hawkins and Law (2006) applied an ecological framework to review risk factors for overweight in preschool children, and summarized the evidence from previous studies on potential factors at four levels: child characteristics, family characteristics, community and social characteristics, and public policies. Table A1 summarized the risk factors examined in their review of 59 studies during 1980 to 2006. As Hawkins and Law (2006) pointed out in the review, there are three gaps in the previous studies: 1) many studies did not control for potential confounders to disentangle interrelationship of some factors; 2) the majority of these studies are cross-sectional designs and

the association established may not indicate causation; 3) very few studies have been done in developing countries despite of the fast increasing prevalence of early childhood obesity.

Table A1 A summary of risk factors for early childhood obesity based on literatures reviewed by Hawkins and Law (2006)

Levels	**Sufficient evidence***	**Insufficient evidence***
Individual	• Breastfeeding • Television and media use • Physical activity	• Weaning • Prolonged bottle use • Drink consumption • Snack food consumption
Family	• Parental overweight • Pre-pregnancy body size • Smoking during pregnancy	• Maternal employment
Community		• Neighborhood safety • Residential proximity to playgrounds or fast food restaurant • School factors • Day care or nursery school factors
Policy	• No studies reviewed involve evaluating impacts of policies on overweight among preschool children	

Notes: *The factor is classified as with sufficient or insufficient evidence based on Hawkins and Law's comments on the various studies reviewed by them. For example, they conclude that "there is extensive evidence on the protective association of breastfeeding on overweight", therefore I categorize breastfeeding as with sufficient evidence.

Several studies were conducted afterwards in the United States, Australia, the UK and other European countries to examine the association between these risk factors and early childhood obesity, having taken into account potential confounding factors (Bammann et al., 2014; Hawkins, Cole, & Law, 2009; Janjua, Mahmood, Islam, & Goldenberg, 2012; Robinson et al., 2015; Suglia, Duarte, Chambers, & Boynton-Jarrett, 2013; Taveras, Gillman, Kleinman, Rich-Edwards, & Rifas-Shiman, 2010; Veldhuis et al., 2012).

Three studies (Bammann et al., 2014; Janjua et al., 2012; Robinson et al., 2015) focused their examination on maternal and early life factors, such as pre-pregnancy body size, excess gestational weight gain, smoking during pregnancy, low maternal vitamin D status, Caesarian section, birth weight, duration of breastfeeding. These studies suggested strong evidence of association between early childhood obesity and some perinatal factors: pre-pregnancy overweight/obesity, excess gestational weight gain, smoking during pregnancy, birth weight and duration of breastfeeding. Robinson et al. (2015) also discovered positive graded associations between number of perinatal risk factors and child's obesity outcome at both 4 and 6 years.

Other cross-sectional studies (Cox et al., 2012; Suglia et al., 2013; Veldhuis et al., 2012), by contrast, concentrated more on modifiable behavioral and social factors in early childhood. Potential risk behaviors identified in these studies include: watching more than 2 hours of television per day, having breakfast < 7 days per week, and short sleep duration. Veldhuis and colleagues (2012) found a positive association between the number of lifestyle-related risk behaviors and the risk for being overweight. Besides behavioral factors, Suglia et al. (2013) also examined the association between early childhood overweight and a cumulative social risk score which integrated maternal reports of intimate partner violence, food insecurity, housing insecurity, maternal depressive symptoms, maternal substance use, and father's incarceration. This study found that the cumulative social risk score was associated with obesity among girls aged 5 years old.

Two cohort studies performed a comprehensive examination of multi-level risk factors (Hawkins et al., 2009; Reilly et al., 2005). In the UK Millennium Cohort Study with a nationally representative, contemporary cohort of British children, Hawkins et al. (2009) examined the

association between 26 potential risk factors across individual, family, community and area levels and the overweight/obese status of these children at 3 years of age. After adjusting for confounders, 9 individual- and family-level factors showed significant association with early childhood overweight, i.e. birthweight Z-score, child's ethnicity, breastfeeding duration, early introduction of solid food, lone motherhood, smoking during pregnancy, parental overweight, pre-pregnancy overweight and maternal employment. Reilly and colleagues (2005) obtained similar findings in an earlier prospective cohort study in the UK. In this study, 8 individual and family characteristics out of 25 putative risk factors were identified to have a significant association with early childhood overweight, including parental obesity, birth weight, very early BMI rebound, catch-up growth, standard deviation score for weight at earlier age, weight gain in first year, short sleep duration, and television watching.

However, community- and policy-level risk factors have seldom been examined in previous researches and very little evidence found on the association between these factors and early childhood overweight. None of community-level factors (easy access to food shops and supermarkets, neighborhood conditions, satisfaction with area where family lives, places for children to play safely, and access to a garden) examined by Hawkins and colleagues (2009) was significant after controlling for confounders. Only one area-level factor, living in Wales, is found related to increased risk of early childhood overweight.

3. Grandparental influences on early childhood obesity

Family environment plays a substantial role in early childhood health than any other stage of life span. Despite numerous research that have been conducted to examine family-level risk factors for early childhood obesity in resource-rich countries, the influences of grandparents

on childhood obesity receive modest attention which may partly be attributed to the prevalence of nuclear family structure in developed countries. In many developing countries and some ethnic minorities in developed countries, in contrast, grandparents are primary caregivers of their grandchildren and play a critical role in the child's health and development. However, studies on early childhood obesity in developing countries, generally speaking, are still in their infancy.

Overall influences

No consensus has been reached on whether grandparental caregiving is a protective or risk factor for childhood obesity. Grandparental influences on childhood obesity can be genetic or behavioral in origin. A few cross-sectional researches in the United States (Formisano et al., 2014; Watanabe, Lee, & Kawakubo, 2011) and Chile (Velez et al., 2008) showed that living with grandparents is significantly associated with a higher risk of children's overweight or obesity after controlling for covariates such as age, gender and socio-economic status. In contrast, Pulgaron and his colleagues (2013) conducted a cross-sectional study with 199 school-aged children of Hispanic descent in Miami and suggested that grandparents played a protective role on BMI Z-score for non- Cuban Hispanic school children. Another study by Lindberg (2015) also revealed that emotional support from grandparents may be protective against early childhood obesity.

Familial Predisposition

Previous studies indicate that the predisposition of obesity and other metabolism diseases of grandparents is associated with elevated risk of children's overweight or obesity (Davis, McGonagle, Schoeni, & Stafford, 2008; Liu et al., 2014). This association can be independent of parental weight and health status. For example, Davis et al (2008) analyzed secondary data of

height and weight from a nationally representative sample of nearly 8000 US families in 2003 and found that grandparental overweight and obese status had an independent association with overweight of children and adolescents aged 5 to 19 years old. Among children with normal-weight parents, grandparental obesity was associated with a significantly increased prevalence of children's overweight, compared with families with normal-weight grandparents. Another cross-sectional survey among 124 families with 7-year-old children in urban areas of Korea (Kim, Lee, Kang, & Song, 2010) also confirmed the association between overweight children and grandparental overweight, especially on the maternal side. A cohort study with 7,249 Japanese children by Liu and colleagues (Liu et al., 2014) found that a maternal family history of hypertension was positively associated with higher risk of child overweight at age 12.

Beliefs and practices

As primary caregivers, either parents or grandparents largely decide the child's dietary and physical activity patterns therefore have critical influences on the weight status of the child. The potential pathways through which the caregivers' beliefs and practices influence young children's obesogenic behaviors may include: 1) caregiving behaviors (e.g. feeding practice, and limiting screen time of grandchildren); 2) role modeling; and 3) modifying household obesogenic environment.

Grandparents were commonly blamed for contributing to children's obesogenic dietary behaviors (Bai Li, Adab, & Cheng, 2014; B. Li, Adab, & Cheng, 2015). Li and colleagues' study (2014) with primary school children in China found that children who were mainly cared for by their grandparents had a higher consumption of unhealthy snacks and sugar sweetened drinks. Other researchers have also reported negative influences of grandparent caregiving on

children's healthy eating habits (Jiang et al., 2007; Pearce et al., 2010). From parents' perspective, grandparents' practices often was considered as undermining the parents' efforts to promote healthy behaviors in children according to the study by Li and colleagues (B. Li et al., 2015). The authors attribute these grandparents' behaviors to their misperception and poor knowledge on child nutrition, e.g. "fat children are healthy and well cared for", and "obesity related diseases can only happen in adults". In another qualitative study with parents and grandparents in Beijing, Jiang and colleagues (2007) also revealed that the grandparents held the belief that children being heavy at a young age would lead to a good nutrition status and tall figure in the future.

However, there is also some evidence regarding the supportive role of grandparents on child feeding and dietary behaviors. Baughcum and colleagues' findings (1998) in their focus group study with a sample of low SES Hispanic mothers are some examples. Mothers reported that they sometimes did not follow the Supplemental Nutrition Program for Women, Infants, and Children (WIC) guidelines and physician recommendations about child feeding, but often seek knowledge for infant feeding and care from their own mothers.

The grandparents' influences on childhood obesity might be modified by other factors, such as cultural significance. Pulgaron et al (2013) revealed a significant interaction between grandparent involvement status and ethnicity for BMI Z-scores (zBMI) in his study with Hispanic school children. In this study, children of Cuban descent did not differ in zBMI for whether or not they had grandparents involved in caregiving, while for other Hispanic origin groups, grandparental caregiving is associated with a lower zBMI instead.

4. Studies on Early childhood Obesity in China

China has developed its own national reference for BMI cutoffs to screen overweight and obesity among school-aged children. In 2005, the Working Group on Obesity in China (WGOC) released the BMI reference and cut-off points for screening overweight and obesity in school-aged children and adolescents based on the 2000 Chinese National Survey on Students Constitution and Health data collected from 216,620 primary and secondary school students aged 7-18 years old (Ji, 2005). Overweight and obesity cut-off points are defined against BMI curves that pass through BMI of 24 and 28 at age of 18 years old respectively.

For preschool-aged children, a national child growth reference was developed by the Capital Institute of Pediatrics (2009) and released by the Ministry of Health in 2009 for clinical use to assess nutritional status of children aged from 1 month to 7 years old. This national growth reference used growth data of children aged under 7 years old collected from a survey performed in nine cities of China in 2005. Age- and gender-specific weight-for-height and BMI Z-score tables and curves were provided, and child overweight was defined as 2 standard deviations above the median against the reference.

Although many researchers advocated for the utilization of national reference to assess nutritional status of children (M. de Onis & Habicht, 1996; Lobstein et al., 2004; Reilly, 2002), most studies in the past decade on the obesity of preschool-aged children in China used international references for assessment, partly because a national reference was not available until 2009. Chen and colleagues (2012) reviewed the definitions of obesity of preschool-aged children used in Chinese publications between 2001 and 2010, and found that most studies used the NCHS/WHO reference population and only one study used a Chinese national reference. It is also found that different cut-off points were used to define child obesity in these studies with a

majority using a cut-off point of >120%, some using >110%, and 1 study using a cut-off point of 115% of the median weight-for-height of the reference population.

No matter what references and cut-offs are used, it is no doubt that the prevalence of early childhood obesity is increasing rapidly in China (S. Chen et al., 2012). For example, the study by Luo and Hu (2002) based on national data from China Health and Nutrition Survey found that the prevalence of obesity among children aged 2-6 years old increased from 4.2% in 1989 to 6.4% in 1997. For the subgroup of children from urban areas in the same study, the increasing trend is significant, with the prevalence of obesity and overweight reaching 12.6% and 28.9% respectively in 1997(J. Luo & Hu, 2002). The large geographical disparity in the obesity prevalence was also revealed in other epidemiological studies (Y. F. Wu et al., 2005) .

A few studies have been performed to identify the risk factors of early childhood obesity in China. A national case control study by He and colleagues (2000) identified five major significant risk factors of obesity among preschool children including birth weight ≥ 4.0 kg, high eating speed, obesity among the child's relatives ≥ 25%, mother's body mass index (BMI) > 25 kg/m^2 and father's BMI > 25 kg/m^2 after controlling for potential confounders. Four out of the five factors except for the high eating speed are related to genetics influences. Li and colleagues (N. Li et al., 2014) also confirmed the birth weight as a risk factor in their study with health care records of 55,925 children aged 3 years and under and discovered a gradient positive association between birth weight and childhood overweight. Besides parental weight status and maternal education level, Jiang et al. (2006) identified two other obesogenic behaviors in a cross-sectional survey with 930 families with young children in Beijing, i.e. food restriction and more than two hours of daily television watching.

Many researchers attributed the geographical disparity in prevalence of childhood obesity to the higher socioeconomic status (i.e. higher income) and related dietary and lifestyle changes (high calories consumption and sedentary pattern) in urban China (J. Luo & Hu, 2002; Y. F. Wu et al., 2005). Yet, role of some socioeconomic factors in early childhood obesity was also found to be dynamic in a national longitudinal study. Fu and George (2015) analyzed multiple waves (1997, 2000, 2004 and 2006) of data from the China Nutrition and Health Survey and revealed that an important political power indicator in the market transformation context of China, the parental state-sector employment was a risk factor for childhood obesity in 1997 but a protective factor in 2006 instead.

In China, grandparents play a critical role in promoting early childhood development and health due to solid intergenerational relationships. Chen and colleagues identified a high rate of co-residence between grandchildren and grandparents using the pooled data from multiple waves (1993, 1997, 2000 and 2004) of China Health and Nutrition Survey (F. Chen, Liu, & Mair, 2011). Approximately 45 percent of grandparents in the sample co-resided with their grandchildren under 7 years old. In addition, 5 percent of the sample households are skipped-generation households in which parents usually migrated to cities for jobs. Extensive childcare for infants and young children were provided by both co-residential and non-coresidential grandparents.

Despite the essential roles of grandparents in childcare, the study on influences of grandparents on early childhood obesity is still in its infancy. The only study by Jiang and colleagues (2007) to examine grandparental influences on overweight/obesity of young children aged 3-6 years in Beijing was a qualitative study with a small convenience sample. The study suggested that grandparents played an important role in planning and cooking family meals, and

shaping children's eating behavior. However, they showed a tendency towards urging the children to overeat due to misconception of good nutrition.

CONCEPTUAL FRAMEWORK

The etiology of early childhood obesity is multi-factorial. Physical inactivity and unhealthy dietary patterns are the major modifiable lifestyle factors contributing to the early childhood obesity epidemic. How does a child develop obesity-related behaviors such as eating habits and physical activity patterns? How do the social relationships and surrounding environment affect children's development and health? The social ecological model developed by Urie Bronfenbrenner (1994), a developmental psychologist, has been widely used to explore child health issues taking into account the influences of the environment surrounding children.

Bronfenbrenner (1994) categorizes the environment surrounding individuals into five levels: the microsystem, the mesosystem, the exosystem, the macrosystem, and the chronosystem. For a young child, the microsystem, including the family and child care center/school is the most important and influential system for their development and health. Their developmental process including established food preferences, eating habits, and physical activities are pre-dominantly decided by their main caregivers in the family, particularly for those children who did not use formal child care services out of home. Therefore this study will mainly focus on the microsystem, exploring the influences of primary caregivers in the family. Figure 1 shows the conceptual framework developed in this study to guide the hypothesis development and testing.

The Health Belief Model suggests that the health motivation, as a result of health related perceptions, is the key to people's health behaviors (Glanz, Rimer, & Viswanath, 2008). In

terms of obesity related behaviors, health perceptions among primary caregivers not only shape their own obesogenic lifestyles (dietary and physical activity patterns) but also influence their caregiving practices to young children therefore affect these children's weight status. Potential pathways of primary family caregivers affecting child obesity include child feeding practices, role modeling behaviors and parenting styles, as suggested by Skouteris et al. (2011) based on his systematic review on parental influences on child obesity.

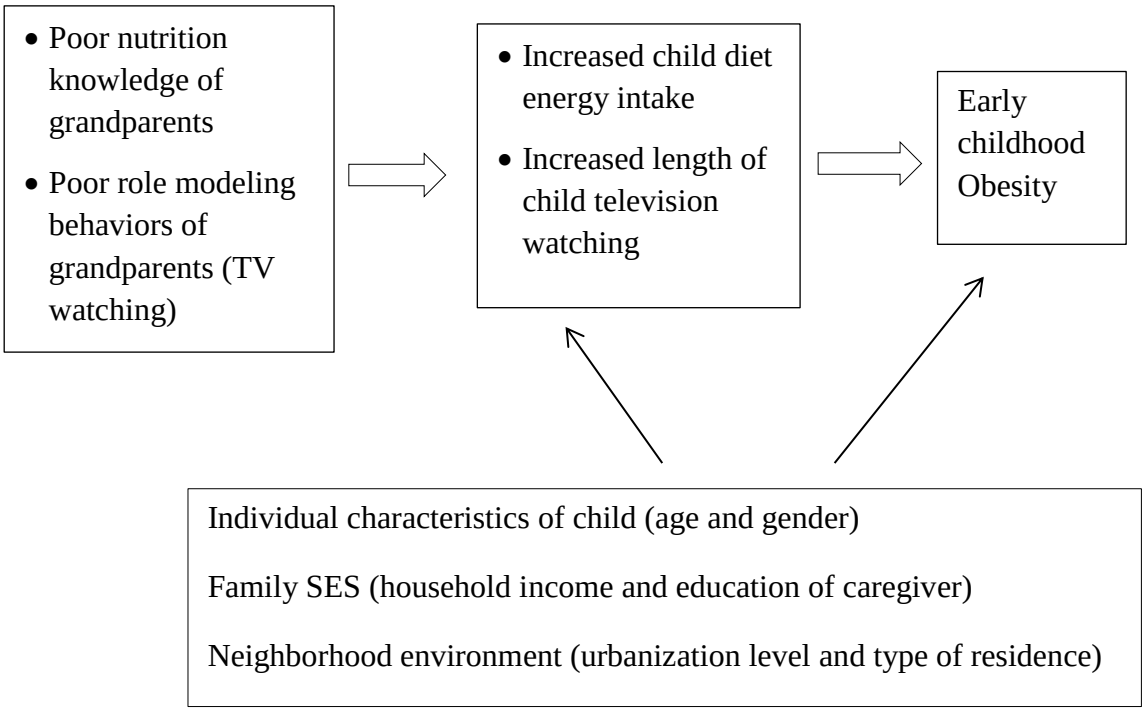
In China, most children aged 0-5 years are taken care of exclusively by family members, mainly by parents and grandparents. Grandparents, especially the co-residing grandparents take a substantial portion of childcare responsibility. Both parents and grandparents largely shape the child's obesity-related behaviors thus influence the child's weight status. This study aims to examine the influences of grandparents on the risks of overweight/obesity among these children through comparing prevalence of obesity among children mainly cared for by grandparents with those cared for by parents.

Compared to parents, grandparents in China are less educated and have less nutrition knowledge, and lower awareness of the obesity problem and its consequence. Applying the Health Belief Model, this study hypothesizes that grandparent caregivers are less likely to be physically active and to have healthy dietary intake; meanwhile they are less likely to provide healthy food, to promote physical activities and to limit sedentary activities (television watching) for their grandchildren. As a result, young children mainly cared for by grandparents are more likely to be overweight or obese compared to those children mainly cared for by parents.

The social ecological model also suggests that the family socioeconomic status and neighborhood environment may influence the caregivers' behaviors therefore affect the risk of

child obesity. Therefore these factors were also included when examining the association between grandparental caregiving and childhood obesity, including two family socioeconomic status factors, i.e. per capita household income and the highest education level of primary caregivers, and two neighborhood environment factors, i.e. type of residence (rural vs. urban) and urbanization level of the neighborhood.

Figure 1 Conceptual framework for assessing the effect of grandparental caregiving on early childhood obesity



RESEARCH QUESTIONS

Research question 1: Are grandparent caregivers of children aged 0-5 years old different from parent caregivers in terms of their health and nutrition knowledge, and their eating and physical activity behaviors?

Research question 2: Are children aged 0-5 years old cared for by grandparents (a) at higher risk for overweight/obesity, (b) more likely to consume higher dietary energy and be sedentary, and (c) more likely to have been breastfed for a shorter duration, compared to those cared for by parents?

Research question 3: Do family socioeconomic status and neighborhood environment influence (moderate) the association between grandparent caretaking and risk of overweight/obesity among children aged 0-5 years old?

These questions will be answered by applying a cross-sectional study design to secondary data from China Health and Nutrition Survey, a national household survey on health and nutrition in China (CHNS, 2015).

DATA AND SAMPLE

This study uses publicly available data from the China Health and Nutrition Survey (CHNS), a collaborative project between the Carolina Population Center (CPC), University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention (CCDC). This ongoing open cohort study,

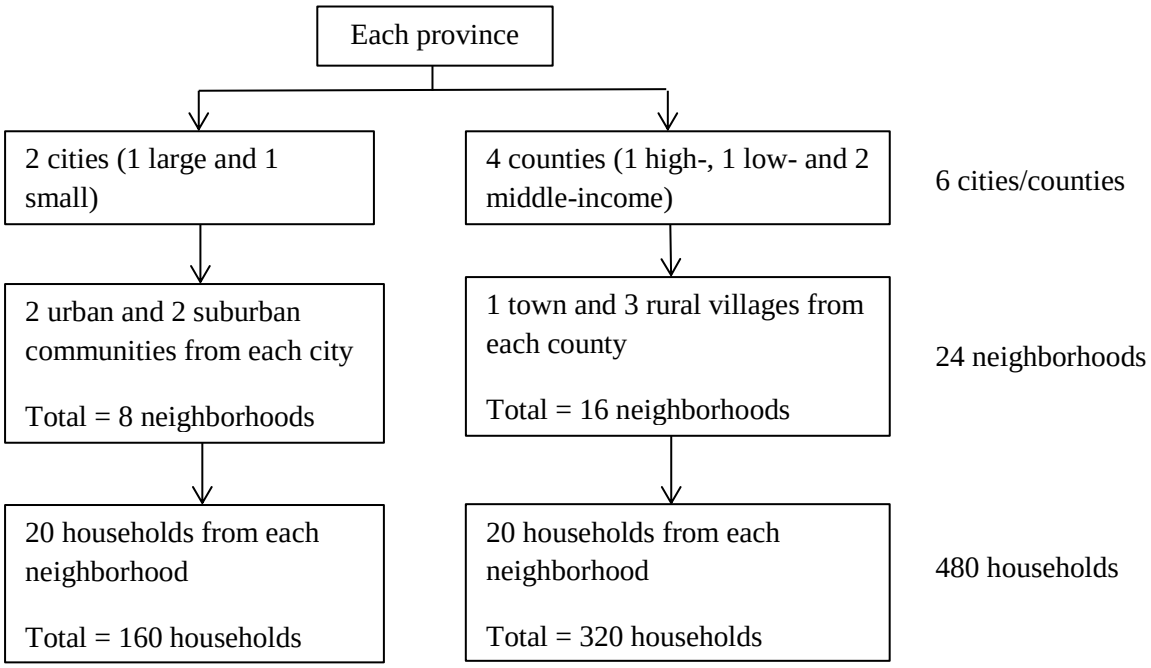
using a longitudinal survey data collection approach, was designed to examine the effects of health, nutrition, and family planning policies and programs implemented by national and local governments on health outcomes, and understand how the social and economic transformation of Chinese society is affecting the health and nutritional status of its population (Popkin, Du, Zhai, & Zhang, 2010; Zhang, Zhai, Du, & Popkin, 2014).

The first round of the CHNS, which gathered data at the individual, family and community levels, was conducted in 1989. Survey respondents were from eight provinces (Liaoning, Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi and Guizhou) that vary substantially in geography, economic development, public resources, and health indicators. A multistage, random cluster sampling process was used to draw the samples from each of these provinces (Zhang et al., 2014). Specifically, two cities (one large and one small, usually the provincial capital and a lower income city) and four counties (one high-, one low- and two middle-income) were randomly selected from each province. Then, two urban and two suburban communities were randomly selected from each city, and one town and three villages were randomly selected from each county. Finally, twenty households were selected from each urban/suburban community, rural village or town. In total, 14,778 individuals from 3,795 households were selected for the survey. For each selected household, face-to-face interviews were conducted in the household to collect detailed demographic and economic information of the family, and health and nutrition information of all household members (see Figure 2).

Eight additional surveys were conducted in 1991, 1993, 1997, 2000, 2004, 2006, 2009, and 2011. Heilongjiang Province was added in 1997, followed by the three largest municipal cities (Beijing, Shanghai and Chongqing) in 2011. By the last survey in 2011, the CHNS had

included 12 provinces/autonomous cities, 288 neighborhoods (60 urban communities, 60 suburban communities, 42 towns and 126 rural villages) with 27,477 individuals from 5,884 households.

Figure 2 Multistage random cluster sampling procedure in each province



For each selected household, a three-day survey through face-to-face interview was conducted at the home of the participants to collect detailed demographic and economic information of the family, and health and nutrition information of all household members (see Table A2).

In addition, a community assessment was conducted for each neighborhood through key informant interviews to gather information such as infrastructures, services, population, prevailing wages, food market, and healthcare facilities (CHNS, 2015).

Table A2 Relevant information collected by CHNS 2011 survey: What, how and on whom

Information collected (what)	**Survey instruments (how)**	**Survey participant (on whom)**
• Household roster • Demographics • Work activities and income • Drinking water, sanitation, and assets	Household questionnaire	Head of the household
• Demographics • Work activities • Household chores and child care • Tobacco, tea, water, coffee, alcohol, and soft drink consumption • Physical activities • Use of health services • Health status • Diet and activity knowledge • Ever-married women under age 52 • Physical measurements	Adult questionnaire	All adults in the household
• Demographics • Work activities • Household chores and child care • Tobacco, tea, water, coffee, alcohol, and soft drink consumption • Physical activities • Body shape and mass media • Diet and activity knowledge • Use of health services • Health status(including physical measurements)	Child questionnaire	All children aged 0-17.99 in the household
• Boy maturation	Boy maturation questionnaire	All boys 12 years old and older in the household
• 3-day record of household food consumption • 3-day record of household meals per person per day • Consumption of snacks and beverage • Individual record of daily food	Dietary questionnaire	All household members

For the purposes of this exploratory study, data relating to children aged 0-5 years from the latest wave (2011) of CHNS will be cross-sectionally examined to investigate the influences

of grandparental caregiving on early childhood obesity. Datasets of children and datasets of their family members were merged based on the same household ID number and the identification variable in the household roster dataset representing relationship between family members.

A total of 883 children aged 0-5 years old were surveyed in 2011 in the China Health and Nutrition Study. Of these 883 children, a total of 197 were excluded: 140 cases with missing physical examination data, 54 cases with implausible anthropometric values (weight-for-age Z-score ≤ -5 or weight-for-age Z-score ≥+5) and 3 cases without living arrangement data. The final analytic sample comprised 686 children aged 0-5 years (Figure 3).

Figure 3 Determination of the final study sample

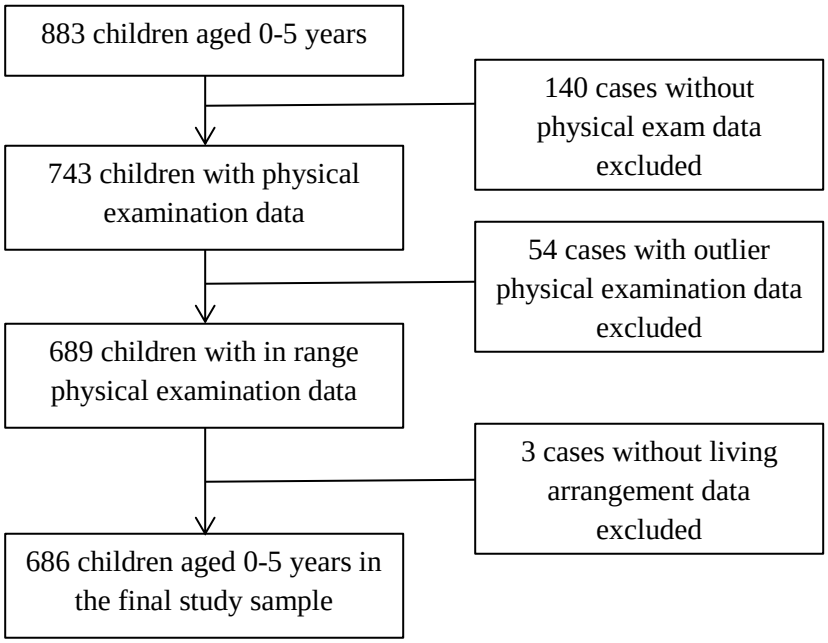


Table A3 compares the characteristics of the analytic sample (686 children) and excluded sample (197 children). The two samples are similar in terms of distribution of gender, age and nationality. However, compared with the analytic sample, the excluded sample has an underrepresentation of children from lower-income families, rural villages and neighborhoods

with lower urbanization index. Given the overrepresentation of urbanized and higher-income households in the analytic sample, the prevalence of childhood obesity in this study may be overestimated. However, the purpose of this study is to examine the association between grandparental caregiving and childhood obesity rather than to infer prevalence of childhood obesity in the population. Therefore, this sociodemographic difference between the analytic and excluded samples is not expected to affect the estimates relevant to the research questions.

Table A3 Comparison of sociodemographic characteristics between analytic sample and excluded sample

Characteristics	**Total sample (n=883)**	**Analytic sample (n=686)**	**Excluded sample (n=197)**	**P-value**
Gender				
Male	490 (55.5%)	382 (55.7%)	108 (54.8%)	p=0.8299
Female	393 (44.5%)	304 (44.3%)	89 (45.2%)	
Age				
$0 \leq$ age < 1	144 (16.3%)	106 (15.5%)	38 (19.3%)	p=0.7484
$1 \leq$ age < 2	179 (20.3%)	141 (20.6%)	38 (19.3%)	
$2 \leq$ age < 3	170 (19.3%)	132 (19.2%)	38 (19.3%)	
$3 \leq$ age < 4	203 (23.0%)	159 (23.2%)	44 (22.3%)	
$4 \leq$ age < 5	186 (21.1%)	148 (21.6%)	38 (19.3%)	
Missing	1 (0.1%)	0 (0.0%)	1 (0.5%)	
Nationality				
Han	782 (88.6%)	607 (88.5%)	175 (88.8%)	p=0.9110
Ethnic minorities	96 (10.9%)	75 (10.9%)	21 (10.7%)	
Missing	5 (0.6%)	4 (0.6%)	1 (0.5%)	
Per capita household income				
$\leq$ RMB5000	283 (32.5%)	200 (29.2%)	83 (41.1%)	p=0.0034*
RMB5001 – RMB10000	236 (26.7%)	195 (28.4%)	41 (20.8%)	
RMB10001 – RMB20000	248 (28.1%)	194 (28.3%)	54 (27.4%)	
RMB20001 – RMB40000	99 (11.2%)	85 (12.4%)	14 (7.1%)	
$\geq$ RMB40001	17 (1.9%)	12 (1.8%)	5 (2.5%)	
Type of residence				
Urban	146 (16.5%)	122 (17.9%)	24 (12.2%)	p=0.1701
Suburban	115 (13.0%)	93 (13.6%)	24 (12.2%)	
County town	152 (17.2%)	114 (16.6%)	38 (19.3%)	
Rural village	470 (53.2%)	357 (52.0%)	113 (57.4%)	

Characteristics	Total sample (n=883)	Analytic sample (n=686)	Excluded sample (n=197)	P-value
Neighborhood urbanization index				
Mean (SD)	67.7 (20.4)	68.7 (20.6)	64.1 (19.3)	p=0.057*

Notes: (1) Due to rounding, percentages may not always add up to 100%. (2) The T-test (for neighborhood urbanization index) and Chi-square test (for all other characteristics) are applied to compare the analytic sample with the excluded sample, *p < 0.10.

MEASUREMENT

This section describes the operational definitions of variables relevant to the analysis. A summary of key variables is presented in Table A4.

1. Early childhood obesity

Early childhood obesity was measured by Weight-for-Height Z-scores of children aged 0-5 years old in this study. Height and weight measurements were obtained in CHNS 2011 survey to calculate Weight-for-Height Z-scores. Height (cm) and weight (kg) were measured by trained health professionals, using standardized protocols. Weight-for-Height Z-scores were calculated based on the WHO 2006 growth reference values, using the SAS macro provided by WHO (http://www.who.int/childgrowth/software/en/). For 0-5 year old children, overweight and obesity status were defined as Weight-for-Height Z-score > 2 standard deviations and >3 standard deviations respectively.

2. Dietary intake (grandparents, parents and children)

Dietary intake data at the household level were collected over three consecutive days in CHNS 2011 survey. Food consumed by the household was estimated by examining daily changes in food inventory by weighing the amount of food available at the beginning and end of each of the three days. Chinese scales with a maximum limit of 15 kilograms and a minimum of 20 grams were used. All food present in the household before initiation of the survey, all food brought into the household during the survey period, all food waste, and all food remaining after last meal of the survey day were weighed (or estimated when weighing was not possible) and recorded. The number of household members and visitors consuming each meal was recorded. Then each household member's average daily dietary intake was calculated from the household survey data using the latest version of the Food Composition Table (FCT) for China.

Individual-level dietary intake data for the same three consecutive days were also collected to cross check the quality of household data. Individuals were asked each day to recall all food consumed in the home and away from home over a 24-hour period for each of the three days. When significant discrepancies were found between the household food consumption data and individual 24-hour recall data, CHNS survey team revisited these households and individuals to resolve these discrepancies.

For the purpose of this study, four dietary intake measurements calculated by the CHNS survey were used to assess the dietary patterns of grandparents, parents and children, i.e. daily energy intake (kcal), daily carbohydrate intake (gram), daily protein intake (gram) and daily fat intake (gram).

3. Television watching (grandparents, parents and children)

Television watching was used as a proxy to assess physical inactivity, and measured from responses to the question, "How much time do you spend during a typical day (on TV watching)?" The amount of time spent by grandparents, parents and children watching television each day was estimated from the reported television watching hours on a typical weekday and weekend day: (hours spent watching television on a week day*5 + hours spent watching television on a weekend day*2)/7.

4. Grandparental caregiving/Living arrangement

Living arrangement was considered a proxy indicator of the extent of grandparent's involvement in caregiving for children aged 0-5 years old. Living arrangements were classified into three categories based on the household roster data: 1) nuclear family in which children live with one parent or two parents only (the least amount of grandparental caregiving involved); 2) three-generation family in which children live with parent(s) and grandparent(s) (medium amount of grandparental caregiving involved); and 3) skipped-generation family in which children live with one grandparent or two grandparents only and parents are not present (the highest amount of grandparental caregiving involved).

5. Individual characteristics of child

Three individual characteristics of child were measured in this study:

(1) Age: child's age was calculated by CHNS in years to one decimal point based on data collected in household roster;

(2) Gender: child's gender was recorded in a dichotomous variable (1=male and 2=female) based on data collected in household roster;

(3) Enrollment in child care: whether a child is enrolled in formal child care was classified based on responses to the following two questions in the child questionnaire, "During the past week, were you taken care of by people who do not live in your household?" (Yes/No), and "Where did the care take place?" A child is classified as enrolled in formal child care if she/he answered "yes" to the first question and answered any of the following items to the second question, "in a neighborhood or private child care center", "in a state child care center", "in a child care center run by a work unit", "at a preschool managed by a primary school" and "at a nursery school".

6. Nutrition and health knowledge (grandparents and parents)

Nutrition knowledge was assessed in two ways:

(1) Grandparents' or parents' awareness of Chinese Dietary Guideline based on their responses to the question, "Do you know about the Chinese Pagoda or the Dietary Guidelines for Chinese Residents? " (Yes/No);

(2) A nutrition knowledge score was calculated from 12 nutrition and health knowledge related questions. Respondents were asked to respond to statements using a Likert scale ranging from 1 to 5 (1=strongly disagree, 5=strongly agree). One point was assigned when the responses were aligned with "correct" answers. For example, "strongly agree" or "agree" responses to the statement, "Reducing the amount of fatty meat and animal fat in the diet is good for one's health" would be assigned 1 point. Responses that were not aligned with "correct" answers were assigned zero points. Hence the possible scores ranged from zero to 12.

7. Family socioeconomic status

Family socioeconomic status (SES) was measured by 1) Per capita household income, and 2) the highest education attainment of the primary caregivers.

Per capita household income was obtained by dividing household total income by household size. In CHNS 2011 survey, each participating household was asked questions about nine potential sources of income: business, farming, fishing, gardening, livestock, non-retirement wages, retirement income, subsidies, and other income. Household total income was conceptualized as the sum of all nine sources of revenue minus expenditure related to the revenue, and was inflated to 2011 Yuan currency values. Household total income can be negative values in certain year when the household reported higher expenses than revenues for various reasons including the cyclic nature of raising livestock, the income from farming and gardening subject to annual weather differences and varying market prices. A few households in the study sample reported negative net household income.

The highest level of caregivers' education was obtained by comparing the education attainment of all parental and grandparental caregivers in each household, and selecting the highest education level. The education attainment of each adult was determined by asking the respondent, "What is the highest level of education you have attained?" Response categories were : 1) less than primary school; 2) primary school; 3) lower middle school; 4) upper middle school degree/vocational degree; 5) college degree or above. This highest education level of caregivers reflected the higher education level of parent(s) in nuclear families, the highest education level of parent(s) or grandparent(s) in three-generation families and the higher education level of grandparent(s) in skipped-generation families.

8. Neighborhood environment

Neighborhood environment was measured using an urbanicity index, and a nominal variable that indicated what type of residence that the child lived in.

CHNS constructed an urbanicity index to capture the social, economic and physical characteristics of each surveyed community (Zhang et al., 2014). This index is a score that ranges from 0 to 120, and is the sum of scores for 12 components: population density, economic activity, traditional markets, modern markets, transportation infrastructure, sanitation, communications, housing, education, diversity, health infrastructure, and social services. The total index score was calculated by CHNS for each of the 288 surveyed neighborhoods in 2011.

Neighborhood environment was also operationalized by a nominal variable: type of residence, which indicates the type of neighborhood where the child lives, i.e. urban community, suburban community, county town or rural village. There are substantial disparities among these neighborhoods in terms of social economic development level, food environment, and access to other infrastructures and social services, etc.

Table A4 Description of key variables examined in this research

Variables	**Operationalization**	**Measurement**	**Data source**
Dependent variables			
1. Early childhood obesity (1) Weight-for-Height Z-score (WHZ) (2) Weight status	Weight-for-Height Z-score against WHO growth reference (2006) Overweight: WHZ > + 2SD	Ratio Nominal 1=overweight 0=normal	Child questionnaire (physical measurements)
2. Dietary intake (child, parent and grandparent)	Daily energy intake (kcal) Daily carbohydrate intake(g) Daily protein intake (g) Daily fat intake (g)	Ratio	Dietary questionnaire
3. Length of daily television watching (child, parent and grandparent)	The amount of time spent on television watching per day	Ratio	Child questionnaire & adult questionnaire

Variables	Operationalization	Measurement	Data source
Independent variables			
4. Grandparental caregiving/Living arrangement	Does the child live with parent(s), grandparent(s) or both?	Nominal 1=nuclear family 2=three-generation 3=skipped-generation	Household questionnaire
5. Child Individual characteristics (1) Age (2) Gender (3) Enrollment in child care	calculated age in years to one decimal point gender reported in household roster whether the child is taken care of by a formal child care facility during the past week	Ratio Nominal 1=male 2=female Nominal 1=enrolled 2=not enrolled	Household questionnaire Household questionnaire Child questionnaire
6. Nutrition knowledge (parent and grandparent) (1) Awareness of nutrition guideline (2) Nutrition knowledge score	The respondent's awareness of nutritional guideline Total scores for 12 nutrition and health knowledge questions	Nominal 1=yes 0=no Ratio	Adult questionnaire
7. Family SES (1) Per capita household income (2) Caregiver education	household total income divided by household size the highest level of education attainment of primary caregivers	Ratio Ordinal 1=less than primary school 2=primary school 3=lower middle school 4=upper middle school 5=college or above	Household questionnaire Adult questionnaire
7. Neighborhood environment (1) Urbanization level (2) Type of residence	urbanicity index calculated from 12 components Type of neighborhood where the child lives	Ratio Nominal 1=urban 2=suburban 3=town 4=rural village	Community survey data Household questionnaire

RESEARCH HYPOTHESES

Hypotheses

This study aims to assess the influences of grandparents' caregiving on early childhood obesity by comparing the prevalence of obesity among children aged 0-5 years old with and without grandparents' caregiving. The following hypotheses will be tested to answer the research questions:

Research question 1: Are grandparent caregivers of children aged 0-5 years old different from parents their health and nutrition knowledge, and their eating and physical activity behaviors?

- **Hypothesis 1.1:** There is no difference in nutrition and health knowledge between grandparent caregivers and parent caregivers.
- **Hypothesis 1.2:** There is no difference in dietary intakes between grandparent caregivers and parent caregivers.
- **Hypothesis 1.3:** There is no difference in the length of daily television watching between grandparent caregivers and parent caregivers.

Research question 2: Are children aged 0-5 years old cared for by grandparents (a) at higher risk for overweight/obesity, (b) more likely to consume higher dietary energy and be sedentary, and (c) more likely to have been breastfed for a shorter duration, compared to those cared for by parents?

- **Hypothesis 2.1:** There is no difference in the prevalence of overweight among children aged 0-5 years from nuclear, three-generation and skipped-generation families.

- **Hypothesis 2.2:** There is no difference in dietary intake among children aged 0-5 years from nuclear, three-generation and skipped-generation families.
- **Hypothesis 2.3:** There is no difference in the length of daily television watching among children aged 0-5 years from nuclear, three-generation and skipped-generation families.

Research question 3: Do family socioeconomic status and neighborhood environment influence (moderate) the association between grandparent caretaking and risk of overweight/obesity among children aged 0-5 years old?

- **Hypothesis 3.1:** There is no association between grandparent caregiving and overweight of children aged 0-5 years old after controlling for individual characteristics (child's age, gender and enrollment in childcare), family socioeconomic status (household income and education attainment of caregiver) and neighborhood environment (urbanization level and neighborhood type).

ANALYSIS METHODS

SAS for Windows Statistical Software Package Version 9.2 was utilized for data processing and analysis in this study. First, univariate analysis was applied to provide descriptive statistics of the study sample, including:

- Demographic characteristics of sample (age, gender, nationality, etc.);
- Family SES and neighborhood environment;
- Prevalence of grandparents' caregiving/different living arrangement;

- Prevalence of child obesity.

Bivariate analysis was applied to examine the hypotheses for research question 1: "Are grandparent caregivers of children aged 0-5 years old different from parents in terms of their obesity related knowledge and behaviors?" Nutrition knowledge, dietary intake, and length of television watching were compared among parental and grandparental caregivers, including mothers, fathers, grandmothers and grandfathers. One-way Analysis of Variance (ANOVA) or Chi-square test was utilized depending on whether the dependent variable is continuous or categorical variable. If the difference among groups is significant, post-hoc tests were also conducted to contrast the mean differences between two groups.

Bivariate analysis was also used to answer question 2: "Are children aged 0-5 years old cared for by grandparents (a) at higher risk for overweight/obesity, (b) more likely to consume higher dietary energy and be sedentary, and (c) more likely to have been breastfed for a shorter duration, compared to those cared for by parents?" Prevalence of overweight, dietary energy intake and length of television watching were compared among children in different living arrangement. One-way ANOVA or Chi-square test was applied based on the type of dependent variable, and post-hoc tests were conducted if necessary as discussed above.

To answer question 3, multivariate analysis (regression analysis) was applied to reexamine the association between grandparental caregiving and child obesity controlling for individual, familial and neighborhood factors. The outcomes variable, childhood adiposity was operationalized separately as a dichotomous variable (overweight vs. normal) and a continuous variable (weight-for-height Z-scores) for this analysis. Logistic regression was used for the dichotomous outcome variable and multiple linear regression analysis was applied for the

continuous outcome variable (WHZ). Interactions between these factors and grandparental caregiving were also tested in the multivariate analysis. To take into account the clustering effect in primary sample units (neighborhood), robust standard errors were calculated to make more conservative estimations.

RESULTS

In this section, the results are being reported in the following order: (1) description of sociodemographic characteristics of the sample, living arrangement and obesity among the children; (2) comparison of obesity related knowledge and behaviors among primary caregivers; (3) comparison of the prevalence of obesity and obesogenic behaviors among children in different living arrangement; and (4) the association between the grandparental caregiving and early childhood obesity after adjusting for family and neighborhood factors.

1. Sociodemographic characteristics of the sample and prevalence of grandparental caregiving and early childhood obesity

Sociodemographic characteristics of the sample: The demographic and socioeconomic characteristics of the sample are presented in Table B1. There are 382 boys (55.7%) and 304 girls (44.3%) in the sample and the mean age is 2.6 years. Approximately 73% of the 686 children are taken care of by only family members; 17% of the children receive formal childcare in childcare centers/nursery schools; and 9% receive informal childcare (mainly being cared for by non-coresiding grandparents). About half of the children live in rural villages while the other half live in urban, suburban and county town areas.

Table B1 Sociodemographic characteristics of the study sample – a comparison among three groups with different living arrangements

Characteristics	Nuclear family (n= 160)	Three-generation (n=410)	Skipped-generation (n= 116)	Total (n= 686)
Gender				
Male	87 (54.4%)	225 (54.9%)	70 (60.3%)	382 (55.7%)
Female	73 (45.6%)	185 (45.1%)	46 (39.7%)	304 (44.3%)
Age				
Mean (SD)	2.6 (1.4)	2.5 (1.4)	2.8 (1.2)	2.6 (1.4)
Nationality				
Han	145 (90.6%)	355 (86.6%)	107 (92.2%)	607 (88.5%)
Ethnic minority	14 (8.8%)	52 (12.7%)	9 (7.8%)	75 (10.9%)
Missing	1 (0.6%)	3 (0.7%)	0 (0.0%)	4 (0.6%)
Per capita household income				
≤ RMB5000	32 (20.0%)	126 (30.7%)	42 (36.2%)	200 (29.2%)
RMB5001 – RMB10000	43 (26.9%)	115 (28.1%)	37 (31.9%)	195 (28.4%)
RMB10001 – RMB20000	54 (33.8%)	110 (26.8%)	30 (25.9%)	194 (28.3%)
RMB20001 – RMB40000	28 (17.5%)	50 (12.2%)	7 (6.0%)	85 (12.4%)
≥ RMB40001	3 (1.9%)	9 (2.2%)	0 (0.0%)	12 (1.8%)
Highest education level of caregivers				
Primary school or none	31 (19.4%)	41 (10.0%)	49 (42.2%)	121 (17.6%)
Junior middle school	48 (30.0%)	159 (38.8%)	36 (31.0%)	243 (35.4%)
Senior middle school	31 (19.4%)	124 (30.2%)	26 (22.4%)	181 (26.4%)
College or above	49 (30.6%)	86 (21.0%)	5 (4.3%)	140 (20.4%)
Missing	1 (0.6%)	0 (0.0%)	0 (0.0%)	1 (0.1%)
Childcare services				
No childcare	97 (60.6%)	314 (76.6%)	89 (76.7%)	500 (72.9%)
Formal childcare	26 (16.3%)	73 (17.8%)	17 (14.7%)	116 (16.9%)
Informal childcare	35 (21.8%)	21 (5.1%)	8 (6.9%)	64 (9.3%)
Missing	2 (1.3%)	2 (0.5%)	2 (1.7%)	6 (0.9%)
Area				
Urban	50 (31.3%)	45 (11.0%)	27 (23.3%)	122 (17.8%)
Suburban	25 (15.6%)	61 (14.9%)	7 (6.0%)	93 (13.6%)
County town	23 (14.4%)	72 (17.6%)	19 (16.4%)	114 (16.6%)
Rural village	62 (38.8%)	232 (56.6%)	63 (54.3%)	357 (52.0%)
Neighborhood urbanicity index				
Mean (SD)	72.4 (22.2)	68.1 (19.0)	65.4 (23.0)	68.7 (20.6)

Notes: Due to rounding, percentages may not always add up to 100%.

Living arrangement: Out of 686 children, 160 children (23.3%) live in nuclear families without grandparents, while the majority (76.7%) co-reside with grandparents including 116 children (16.9%) living in skipped-generation families and 410 children (59.8%) living in three-generation families. Table B1 summarizes the sociodemographic characteristics of children with different living arrangement.

Prevalence of overweight/obesity: Out of the 686 children examined in the survey, 106 children are overweight (weight-for-height Z-score > 2) or obese (weight-for-height Z-score > 3). The overall prevalence of overweight/obese for the study sample is 15.5% (Table B2). The mean weight-for-height Z-score for the 686 children is 0.53 with a standard deviation of 1.50.

Table B2 Prevalence of obesity and weight-for-height Z-score among children aged 0-5 years in 2011 by living arrangement

Nutritional status	Nuclear family (n=160)	Three-generation (n=410)	Skipped-generation (n=116)	Total (n=686)
Childhood Obesity				
Normal	130 (81.3%)	357 (87.1%)	93 (80.2%)	580 (84.6%)
Overweight	17 (10.6%)	34 (8.3%)	14 (12.1%)	65 (9.5%)
Obese	13 (8.1%)	19 (4.6%)	9 (7.8%)	41 (6.0%)
Weight-for-height Z-score				
Mean (SD)	0.78 (1.40)	0.38 (1.52)	0.72 (1.53)	0.53 (1.50)

Notes: Overweight: weight-for-height Z-scores > 2; obese: weight-for-height Z-scores > 3.

2. Comparison of obesity-related knowledge and behaviors among caregivers

Obesity-related knowledge and behaviors of grandparent caregivers were compared with parent caregivers to answer the first research question: Are grandparent caregivers different from parents in terms of their obesity related knowledge and behaviors?

Table B3 presents a comparison among mothers, fathers, grandmothers and grandfathers in terms of their obesity-related perceptions and behaviors, including awareness of national nutrition guideline, nutrition knowledge score, the length of daily television watching, daily dietary energy intake, daily carbohydrate intake, daily protein intake and daily fat intake. Overall, primary caregivers have insufficient nutrition knowledge. Only 16.5-31.6% of primary caregivers reported that they knew about national nutrition guideline. There are significant differences in each knowledge and practice indicator across caregiver groups ($p<0.01$).

Table B3 Comparison of obesity-related knowledge and behaviors among caregivers

Obesity-related knowledge and practices		**Father (n=396)**	**Mother (n=512)**	**Grandfather (n=398)**	**Grandmother (n=485)**	**P**
Awareness of nutrition guide	N (%)	125 (31.6%)	144 (28.1%)	83 (20.9%)	80 (16.5%)	p<0.01
Nutrition knowledge score	M (SD)	8.9 (2.0)$^{\blacklozenge}$	8.9 (1.9)*	8.6 (2.1)	8.3 (2.3)*$^{\blacklozenge}$	p<0.01
Daily TV watching (min)	M (SD)	99.1 (71.1)$^{\blacklozenge\#}$	109.5 (75.3) *	125.1 (76.5) *$^{\blacklozenge}$	116.2 (81.9)$^{\#}$	p<0.01
Daily energy intake (kcal)	M (SD)	2135 (687)$^{\blacklozenge\#}$	1735 (606)$^{\blacklozenge\$}$	2036 (652) *$^{\$\&}$	1747 (581)$^{\#}$*$^{\&}$	p<0.01
Daily carbo intake (gram)	M (SD)	281.5 (114.7)$^{\blacklozenge\#}$	224.8 (90.9)$^{\#\$}$	271.7 (107.6)*$^{\$}$	234.6 (95.0)*$^{\blacklozenge}$	p<0.01
Daily protein intake (gram)	M (SD)	75.8 (27.9)$^{\blacklozenge}$*$^{\$}$	60.9 (22.6)$^{\blacklozenge\#}$	69.0 (24.4) *$^{\#\&}$	59.3 (24.3)$^{\$\&}$	p<0.01
Daily fat intake (gram)	M (SD)	75.9 (37.6)$^{\blacklozenge}$*	65.5 (40.3)$^{\blacklozenge}$	70.2 (33.6)$^{\#}$	63.3 (30.9) *$^{\#}$	p<0.01

Notes: Chi-square test was applied to compare the proportion of caregivers who are aware of nutritional guideline; ANOVA was used to test difference in other indicators; Tukey's Studentized Range test was use for post hoc testing between groups if $p<0.05$; * $^{\blacklozenge\#\$\&}$ marks the groups between which there is a significant difference; $\alpha=0.05$.

Analysis was then conducted to compare grandparents with parents, and compare female with male caregivers (Table B4). Compared to parental caregivers, the proportion of grandparental caregivers who knew about the national nutrition guideline was significantly smaller ($p<0.01$), and their nutrition knowledge score was also significantly lower ($p<0.05$). On

average, grandparents watched television for around 120 minutes per day which is significantly longer than the time parents spent on television watching ($p<0.01$). Regarding dietary intake, grandparental caregivers consumed significantly less protein and fat than parents did ($p<0.01$). There was no significant difference in daily consumption of dietary energy and carbohydrate between grandparents and parents.

Table B4 Comparison of obesity-related knowledge and behaviors between parents and grandparents, and between male and female caregivers

Obesity-related knowledge and practices		**Grandparents vs. Parents**			**Female vs. Male**		
		Grandparent (n=885)	**Parent (n=908)**	**P-value**	**Female (n=997)**	**Male (n=794)**	**P-value**
Awareness of nutrition guide	N (%)	163 (18.5%)	269 (30.0%)	p<0.0001	224 (22.5%)	208 (26.2%)	p=0.0669
Nutrition knowledge score	M (SD)	8.4 (2.2)	8.9 (2.0)	p<0.0001	8.6 (2.1)	8.7 (2.0)	p=0.3070
Daily TV watching (min)	M (SD)	120.2 (79.6)	105.0 (73.6)	p<0.0001	112.7 (78.6)	112.2 (75.0)	p=0.8815
Daily energy intake (kcal)	M (SD)	1877 (631)	1910 (672)	p=0.2985	1741 (594)	2085 (671)	p<0.0001
Daily carbo intake (gram)	M (SD)	251.4 (102.5)	249.5 (105.7)	p=0.7051	229.6 (93.0)	276.6 (111.2)	p<0.0001
Daily protein intake (gram)	M (SD)	63.7 (24.8)	67.4 (26.1)	p=0.0024	60.1 (23.4)	72.4 (26.4)	p<0.0001
Daily fat intake (gram)	M (SD)	66.4 (32.3)	70.0 (39.5)	p=0.0352	64.4 (36.0)	73.0 (35.7)	p<0.0001

Notes: Chi-square test was applied to compare the proportion of caregivers with knowledge of nutritional guideline; independent sample t-test was used to test difference in other indicators between groups; $\alpha=0.05$.

The comparison between female and male caregivers shows that mothers and grandmothers consumed less energy, carbohydrate, protein and fat than fathers and grandfathers did ($p<0.01$). There was no significant difference in nutrition knowledge and the length of daily television watching between female and male caregivers.

Further analysis was conducted to compare obesity-related knowledge and practices of adult caregivers across different living arrangement (Table B5). Significant differences were observed in knowledge of nutrition guideline, nutrition knowledge index, length of daily TV watching, protein intake, and fat intake. Adult caregivers in nuclear family (parents) had a significantly higher level of knowledge and watched television less ($p<0.05$) and consumed more protein and fat.

Table B5 Comparison of obesity-related knowledge and practices among primary caregivers by living arrangement

Obesity-related knowledge and practices		Nuclear family (n= 291)	Three-generation (n=1295)	Skipped-generation (n= 207)	P-value
Awareness of nutrition guide	N (%)	87(29.9%)	297(23.0%)	48(23.2%)	p=0.0420
Nutrition knowledge score	M (SD)	8.9(1.9)*	8.7(2.1)	8.4(2.3)*	p=0.0115
Daily TV watching (min)	M (SD)	100.2(63.1)*♦	114.4(78.1)*	118.0(85.7)♦	p=0.0102
Daily energy intake (kcal)	M (SD)	1945(637)	1879(650)	1915(686)	p=0.2657
Daily carbo intake (gram)	M (SD)	245.2(99.7)	250.6(104.1)	256.9(110.3)	p=0.4758
Daily protein intake (gram)	M (SD)	68.9(25.5)*	64.8(24.2)*	65.9(32.5)	p=0.0445
Daily fat intake (gram)	M (SD)	74.7(40.3)*	66.9(34.9)*	67.3(36.6)	p=0.0041

Notes: Chi-square test was applied to compare the proportion of caregivers with knowledge of nutritional guideline; ANOVA was used to test difference in other indicators across three groups; Tukey's Studentized Range test was use for post hoc testing between groups if $p<0.05$; *and ♦ marks the groups between which there is a significant difference; $\alpha=0.05$; missing data (0-5%) were excluded when calculating descriptive statistics and testing hypothesis on group difference.

3. Prevalence of Early Childhood Obesity and obesogenic behaviors among children with different living arrangement

The prevalence of obesity and obesogenic behaviors among children with different living arrangement was compared to answer the second research question: Are children aged 0-5 years

old cared for by grandparents (a) at higher risk for overweight/obesity, (b) more likely to consume higher dietary energy and be sedentary, and (c) more likely to have been breastfed for a shorter duration, compared to those cared for by parents?

Table B6 compares the prevalence of overweight and obese among children groups in different living arrangements. The prevalence is highest for children living in skipped-generation families (19.8%), followed by children living in nuclear families (18.8%) and the prevalence is the lowest for children living in three-generation families (12.9%). The difference is marginally statistically significant (p=0.0807).

Table B6 Comparison of prevalence of childhood obesity and weight-for-height Z-score by living arrangement

Nutritional status	Nuclear family (n=160)	Three-generation (n=410)	Skipped-generation (n=116)	P-value
Childhood Obesity				
Normal	130 (81.3%)	357 (87.1%)	93 (80.2%)	P=0.0807
Overweight	30 (18.8%)	53 (12.9%)	23 (19.8%)	
Weight-for-height Z-score				
Mean (SD)	0.78 (1.40)*	0.38 (1.52)*	0.72 (1.53)	P=0.0053

Notes: Overweight includes both overweight (weight-for-height Z-scores > 2) and obesity (weight-for-height Z-scores > 3); Chi-square test was applied to compare the prevalence of overweight; ANOVA was used to compare weight-for-height Z-scores among three groups; Tukey's Studentized Range test was used for post hoc testing between groups, and * marks the groups between which there is a significant difference; α=0.05.

Mean weight-for-height Z-scores were also compared using one-way analysis of variance (ANOVA). Since the difference in Z-scores across different living arrangement is statistically significant ($F_{2, 683}$=5.27, p=0.0053), Tukey's Studentized Range (HSD) test was applied to further compare the means of each pair of groups. The mean score for children from three-generation family is significantly lower than that for children from nuclear family (p<0.05) and

that for skipped-generation family ($p<0.05$), while the difference in the means of nuclear family group and skipped-generation family group is not statistically significant ($p>0.05$).

Prevalence of obesogenic behaviors among children: The mean dietary energy intake and length of daily television watching were compared across child groups with different living arrangement. The results are presented in Table B7.

There is a significant difference in the average length of daily television watching across groups ($p=0.039$). Children from skipped-generation families had the longest mean time of television watching per day (71.8 ±76.2 minutes), followed by children from nuclear families (62.3±70.4 minutes), and children from three-generation family (54.4 ±62.1minutes). Tukey's Studentized Range test was applied to compare the means of each pair of groups. The results show that only the difference in mean TV watching time between skipped-generation family group and three-generation family group is statistically significant ($p<0.05$).

Table B7 Comparison of obesogenic behaviors among children by living arrangement

Obesogenic behavior	**Nuclear family (n= 160)**	**Three-generation (n=410)**	**Skipped-generation (n= 116)**	**P-value**
Length of daily TV watching				
Mean (SD)	62.3 (70.4)	54.4 (62.1)*	71.8 (76.2)*	p=0.0390
Daily energy intake				
Mean (SD)	1020.6 (441.6)	1013.5 (400.0)	1051.4 (481.4)	p=0.7965
Daily carbo intake				
Mean (SD)	135.4 (59.1)	131.9 (55.6)	136.3 (60.7)	p=0.7922
Daily fat intake				
Mean (SD)	37.1 (24.5)	38.2 (19.4)	39.7 (25.4)	p=0.7479
Daily protein intake				
Mean (SD)	36.1 (16.2)	35.2 (15.3)	37.2 (21.4)	p=0.6512

Notes: ANOVA was used to test difference across three groups, and p-values are presented in the table; Tukey's Studentized Range test was use for post hoc testing of TV watching hours between groups, and * marks the groups between which there is a significant difference; $\alpha=0.05$.

On average, children from skipped-generation family consumed a higher level of dietary energy (1051.4 ±481.4kcal) than children from nuclear family (1020.6 ±441.6 kcal) and children from three-generation family (1013.5 ±400.0 kcal). Similar trends were also observed with the daily intake of carbohydrate, fat and protein, but none of these differences in dietary intake reached statistical significance.

4. Factors Moderating the Association between Grandparental Caregiving and Early Childhood Obesity

Multivariate analysis was applied to examine the association between living arrangement controlling for potential confounding factors, including the individual characteristics of children (age, gender and enrollment in childcare), family socioeconomic status (caregiver education and household income) and neighborhood environment factors (area of residence and neighborhood urbanization index). This analysis is to answer the third research question: Do family socioeconomic status and neighborhood environment influence (moderate) the association between grandparent caretaking and risk of overweight/obesity among children aged 0-5 years?

First, a multiple linear regression analysis was conducted to estimate the association between early childhood obesity and the living arrangement (proxy indicator for grandparental caregiving) controlling for abovementioned potential confounders. The dependent variable, weight-for-height Z-score of a child, is a continuous variable. The independent variable of interest, living arrangement, is a categorical variable. Control variables include three continuous variables: age, household income and neighborhood urbanization index, and four categorical variables: gender, enrollment in formal childcare, highest educational attainment of caregiver, and area of residence.

Table B8 shows the results of ordinary least squares (OLS) regression analysis with 678 complete cases (8 cases excluded due to missing values). Model 1 estimated the regression coefficients and standard errors with raw data while in model 2, a more conservative robust standard error was calculated which takes into account the clustering of the sample in the primary sample unit (neighborhood) and the stratification of the sample based on the area of residence.

Table B8 OLS regression of child weight-for-height Z-score on living arrangement, child demographic characteristics, family and neighborhood socioeconomic status indicators (n = 678)

Predictors	**Range**	**Model 1**		**Model 2**	
		B	SE	B	SE
Nuclear family [a]	0/1	0.301*	0.145	0.301*	0.152
Skipped-generation family [a]	0/1	0.387*	0.165	0.387*	0.177
Age	0-5	-0.107*	0.047	-0.107*	0.050
Gender (1=male)	0/1	-0.072	0.116	-0.072	0.123
Enrollment in childcare	0/1	0.048	0.172	0.048	0.167
Per capita household income (units of 1,000 Yuan)		0.009	0.006	0.009	0.005
Highest education attainment of caregiver (1=senior middle school or higher)	0/1	0.080	0.146	0.081	0.151
Neighborhood urbanization index	0-120	-0.003	0.004	-0.003	0.006
Town [b]	0/1	0.255	0.193	0.255	0.273
Suburban [b]	0/1	0.468*	0.189	0.468	0.289
Urban [b]	0/1	0.465*	0.224	0.465	0.287
Constant		0.597	0.287	0.597	0.397
R^2		0.048		0.048	

Analysis of variance: (1) model 1, $F_{11, 666}=3.03$, $p<0.001$; (2) model 2, $F_{11, 203}=2.98$, $p<0.01$.
*$p<0.05$; [a] reference group is three-generation family; [b] reference group is rural villages.

In both models, the living arrangement significantly affects children's weight-for-height Z-scores ($p<0.05$). Compared to children living in three-generation families, the mean weight-for-height Z-scores for children living in nuclear families or skipped-generation families are

greater by 0.3 and 0.4 respectively. Age is a significantly negative predictor of child obesity in both models ($p<0.05$). The mean Z-scores are lower for older children than younger children. Every one year increase in age corresponds to an increase of 0.1 in the mean weight-for-height Z-score. The area of residence (rural village, town, suburban, or urban neighborhood) is a significant predictor for children's weight-for-height Z-scores in model 1 ($p<0.05$) but not in model 2.

Potential interactions between living arrangement with all other control variables were also examined and none of them are statistically significant (data not shown).

In addition, logistic regression analysis was conducted to predict the risk of early childhood obesity associated with grandparent caregiving. The dependent variable, weight-for-height Z-score of a child, was transformed into a dichotomous variable for this analysis. The dichotomous dependent variable is coded as 1 if the child is classified as overweight/obese (weight-for-height Z-score>2) and 0 otherwise (weight-for-height Z-score≤2). The independent variable and control variables are the same as those included in the multiple linear regression analysis. The operational definitions of dependent and independent variables included in the logistic analysis are summarized in Table B9.

Table B9 Operational definitions of variables included in the multivariate analysis

Variables	Operational definitions
Dependent variable	
Child obesity	1=overweight/obese, 0=normal
Independent variable	
Living arrangement	
Three-generation family	Reference group
Nuclear family	1= nuclear family, 0=otherwise
Skipped-generation family	1=skipped-generation family, 0=otherwise
Control variables	

Variables	Operational definitions
Age	Continuous, in years, ranges from 0-5
Gender	1=male, 0=female
Enrollment in formal childcare	1=yes, 0=no
Caregiver Education	1=senior middle school or higher, 0=junior middle school or lower
Household income	Continuous, in 1000 Yuan, per capita household income
Area of residence	
Rural village	Reference group
County town	1=county town, 0=otherwise
Suburban community	1=suburban, 0=otherwise
Urban community	1=urban, 0=otherwise
Urbanization index	Continuous, ranges from 0-120

The results of logistic regression reveal that after controlling for confounders, there is still significant association between living arrangement and childhood obesity. The adjusted odds ratio (OR) and 95% confidence interval (95% CI) for each independent variable of the regression model is presented in Table B10. Compared with children in three-generation families, children in skipped-generation families are twice more likely to be overweight/obese (adjusted OR: 2.213, 95% CI: 1.228-3.989). The odds of being obese for children in nuclear families are not significantly different from those in three-generation families.

Being younger in age, living in a family with higher income and living in suburban area are also significantly associated with child overweight. Compared with those aged one year younger, children who are one year older are 20% less likely to be overweight (adjusted OR: 0.769, 95% CI: 0.641-0.923). Every incremental of RMB1000 in per capita household income corresponds to 1.8% increase in risk of children being overweight (adjusted OR: 1.018, 95% CI: 1.000-1.037). Living in suburban area doubles the risk of early childhood obesity (adjusted OR: 1.949, 95% CI: 1.005-3.779).

Table B10 Results of Multivariate Logistic Regression of Early Childhood Obesity on Living Arrangement (n=678)

Explanatory variables	OR (95% CI)	P-value
Living arrangement		
Three-generation family	1.000	
Nuclear family	1.426 (0.837-2.431)	0.1919
Skipped-generation family	2.213 (1.228-3.989)	0.0082*
Age		
Age in years	0.769 (0.641-0.923)	0.0049*
Gender		
Female	1.000	
Male	0.888 (0.575-1.369)	0.5896
Enrollment in formal childcare		
No	1.000	
Yes	1.269 (0.645-2.499)	0.4904
Caregiver Education		
Below senior middle school	1.000	
Senior school or higher	1.383 (0.797-2.400)	0.2482
Household income		
Per capita household income (1,000 Yuan)	1.018 (1.000-1.037)	0.0506
Area of residence		
Rural village	1.000	
County town	1.055 (0.501-2.219)	0.8882
Suburban	1.949 (1.005-3.779)	0.0482*
Urban	1.357 (0.604-3.050)	0.4604
Neighborhood development		
Neighborhood urbanization index	0.999 (0.983-1.015)	0.8760

Notes: OR=adjusted odds ratio, CI=confidence interval, *$p \leq 0.05$.

DISCUSSION

Family context has a profound impact on child development and wellbeing, particularly in early childhood. In the emerging epidemic of childhood obesity, it is critical to examine the influences of family in the etiology of obesity thus to identify effective policies and programs to halt the rising obesity problem. This study is to examine the role of grandparents, the primary

family caregivers for the preschoolers in China, in affecting these children's risk of being overweight or obese. In China, grandparents have been long blamed by popular media and academia community (Jiang et al., 2007; B. Li et al., 2014; B. Li et al., 2015) for promoting the childhood obesity. This study, however, shows that the foregoing claim may not be well supported by the empirical evidence from the China Health and Nutrition Survey.

1. Comparison between parental and grandparental caregivers

Primary caregivers of children, either parents or grandparents can influence children's obesogenic behaviors both directly (e.g. providing food for children) and indirectly (e.g. role modeling). Many studies suggested that grandparents are not good primary child caregivers due to their lower education level, insufficient health and nutrition knowledge, and poor parenting style and skills (Jiang et al., 2007; B. Li et al., 2015; J. Y. Luo et al., 2008; Tan et al., 2010).

In this study, obesity related knowledge and behaviors of grandparents were compared with those of parental caregivers to examine whether grandparents are as capable as parents to provide healthy food and positive role models. The results confirmed the findings from other studies (previously cited) that grandparents have less health knowledge and watch longer hours of television than parents do.

2. Risk of obesity among preschool children in different living arrangement

This research then compared the prevalence of early childhood obesity among families with different living arrangement. The living arrangement was used as a proxy indicator in this study to measure and categorize the amount/level of grandparental involvement in preschool child caregiving, i.e. nuclear family (least amount of grandparental caregiving), three-generation

family (medium amount of grandparental caregiving) and skipped-generation family (high amount of grandparental caregiving).

Surprisingly, preschool children living in three-generation families where they receive medium amount of grandparental caregiving have a lower prevalence of overweight and obesity (12.9%) than that of children in nuclear families (18.8%) and skipped-generation families (19.8%) at a near significance level ($p=0.0807$). The comparison of mean weight-for-height Z-scores for children in different living arrangement shows a significant higher mean Z-score of children in nuclear families than that of children in three-generation families ($P<0.05$). No significant difference in weight-for-height Z-score was detected between children in nuclear families and skipped-generation families.

This relationship remains after controlling for potential confounders, including age and gender of the child, enrollment in childcare facilities, highest education level of adult caregivers, per capita household income, area of residence and neighborhood urbanization index. After adjusting for these factors, children in nuclear families and skipped-generation families both showed an increased risk of being overweight or obese than those living in three-generation families.

The results of comparison of obesogenic behavior indicators (TV watching and dietary intake) were keeping with the revealed association between grandparental caregiving and obesity (Table C1). Children in three-generation families had the shortest TV watching and the lowest dietary energy intake among the three groups, although no significant difference in dietary intake was detected across groups in this study.

Table C1 A summary of associations between outcome indicators with living arrangement

Living arrangement	Grandparental caregiving	Length of TV watching	Dietary energy intake*	Overweight prevalence
Nuclear family	Least	Middle	Middle	Middle
Three-generation family	Medium	Lowest	Lowest	Lowest
Skipped generation family	Most	Highest	Highest	Highest

Notes: *the difference is not statistically significant.

3. Grandparental caregiving did not increase the risk of early childhood obesity

The comparison between nuclear families and three-generation families led to the key conclusion of this study: grandparental caregiving did not increase the risk of the grandchildren being overweight. This finding is discordant with a few studies conducted in urban China which concluded that grandparent caregiving increased the risk of their grandchildren being overweight or obese (Jiang et al., 2007; B. Li et al., 2014; B. Li et al., 2015).

In her small-scale qualitative study in Beijing, Jiang et al. (2007) reported that three-generation families did not provide a healthy diet for children despite of high health knowledge of parents. Grandparents who have wrong perception on healthy weight usually have a tendency to overindulge their grandchildren therefore counter the efforts of parents and teachers to keep the children healthy. This conclusion, however, is subject to bias since all the interviewees (parents and grandparents) are from three-generation families and no comparison was made with nuclear families. Li and colleagues' study (2014; B. Li et al., 2015) in two cities of China also found that children mainly cared for by grandparents had more obesogenic behaviors, and a higher risk of being overweight/obese. However, children involved in their study are at school age and the study failed to rule out some key environmental risk factors for school-aged children, e.g. peer pressure for children to consume unhealthy snacks (Chee, 2000).

This study found that for preschoolers in China, those cared for by grandparents in three-generation families are healthier than those cared for merely by parent(s). The possible explanations will be discussed later in this section.

4. Children taken care by grandparents in skipped-generation family were at higher risk of overweight/obesity

This study also revealed that preschool children from skipped-generation families where they were taken care of only by co-residing grandparent(s) had a significant higher risk of being overweight/obesity compared to those children in three-generation families. This key finding highlighted the vulnerability of children in skipped-generation families, mainly in rural areas. They have been known as left-behind children in China whose parents migrated from rural area to cities for employment, and they were left behind for grandparents to take care of.

This population of left-behind children has received considerable media coverage and academic attention during the past decade due to its magnitude (one-fifth of all children in the country) and the profound impacts that family separation has on children (Lin et al., 2015). Over 40% of these left-behind children are younger than five years old, and the total number is 23.4 million in 2013, including children separating from one parent or both parents (Lin et al., 2015). The undernutrition problems of this group of young children, particularly stunting and iron deficiency anemia, has been documented by studies and become a public concern (J. Y. Luo et al., 2008).

This research, however, revealed that this group of young children may bear the "double burden" of underweight and overweight malnutrition. Many factors might have contributed to

the emerging high prevalence of obesity in this children group, including poor knowledge and feeding practice of less educated grandparental caregivers, underutilization of regular health care to monitor child growth, less opportunities for breastfeeding, unhealthy food as compensation for separating from parents, using television for babysitting and so on. In this research, children living in skipped-generation family were found watching longer hours of television. A survey conducted by J. Y. Luo et al. (2008) in rural China showed that the breastfeeding rate for left-behind children were significantly lower and the weaning age was earlier compared to the control group. Interviews with grandparents in Beijing by Jiang et al. (2007) also suggested that grandparents do have a motivation to overfeed their grandchildren since "They [the parents] cannot say that I haven't done my best in looking after the child if they baby is big".

5. Plausible alternative explanations for association between grandparental caregiving and early childhood obesity

In the debating about grandparents' roles in promoting childhood obesity, it is usually hypothesized that the lower level of health knowledge and parenting skills among grandparents would lead to obesogenic practices among their grandchildren (e.g. unhealthy snacks, sedentary lifestyle) therefore increase the risk of these young children being overweight or obese. This empirical study shows that it may not necessarily be the case for the preschoolers in China. The grandparents did show inferior health knowledge and longer television watching behaviors than parents do, but it did not directly translate into poor caregiving for their grandchildren and higher risk of their grandchildren being overweight. Instead, children living in three-generation families where a substantial amount of grandparental caregiving is usually involved have a significant lower risk of overweight than their counterparts living in either nuclear families (less

grandparental caregiving involved) or skipped-generation families (more grandparental caregiving involved).

One of the plausible alternative explanations could be the higher total amount of caregiving by all the caregivers to the young child in the three-generation families reduces the risk of the young child being overweight. A large-scale longitudinal study of early child care conducted by the National Institute of Child Health and Human Development (NICHD) has concluded that child-adult ratio plays an important role in predicting quality of caregiving for toddlers and preschoolers (Health & Network, 2000). Across the five different types of early child care arrangement and ages of children, the highest level of positive caregiving was provided by in-home caregivers (parents and grandparents) caring for only one child, closely followed by home-based arrangements with relatively smaller child-adult ratio.

Compared to the other two types of living arrangement, the three-generation family generally involves a higher number of in-home caregivers for the young child and higher amount of special attention to the young child in the household. This might lead to relatively healthy eating at home and more physical activities accompanied by caregivers. For the nuclear families, the higher health knowledge and parenting skills of parents may help to offset the impacts of lower level of caregiving, and some families also receive help from non-coresiding grandparents for childcare. In contrast, children in the skipped-generation families may fall into the most vulnerable situation due to not only the poor knowledge and skills of grandparents but also the limited amount of caregiving and special attention they were able to provide to the young children.

In addition, the interactions between family members in three-generation families may form a healthier environment for young children. Although parents and grandparents may have conflicting perceptions about nutrition and child obesity (Jiang et al., 2007), their interactions may help modify the family environment to be healthier, e.g. increasing access to healthy food, and restricting television watching. The intergenerational support may also help reduce social risks of the family (e.g. stress of family members) which are well documented risk factors for early childhood obesity (Suglia et al., 2013).

6. Conclusions

In summary, this study concluded that: (1) Compared with parents, grandparents had lower nutrition knowledge and watched television longer; (2) grandparental caregiving does not increase the risk of obesity for preschoolers; instead, children in the care of grandparents in three-generation families are at lower risk than those cared for only by parent(s) or only by grandparent(s).

STRENGTHS AND LIMITATIONS

Despite of the critical role of grandparent caregivers in shaping nutrition status of young children in China, there is a scarcity in studies examining grandparental impacts on early childhood obesity. This study added empirical evidence to the current knowledge base on the role of grandparent caregiver in early childhood obesity so as to better inform family-oriented program planning and policy design regarding early childhood obesity prevention in China.

One of the strengths of this study is its focus on preschool-aged children to whom the familial environment is more essential than it to other age groups. By focusing the study on preschoolers, this study avoided the mingling of influences from families, schools and peers as for older children. Secondly, this study operationalized the grandparental caregiving as three types of living arrangement rather than using a dichotomous variable (with or without presence of grandparents), which made it possible to examine the impacts of grandparents in different situations (with or without presence of parents). Lastly, the study sample drawn from the China Health and Nutrition Survey represented regions of diverse economic and social development levels, and was similar to the national profile in terms of gender, age and nationality distribution (Table C2). This representative data increased the generalizability of the conclusion from this study compared other studies solely based on urban data.

Table C2 Comparison of demographic characteristics of the study sample with China 2010 census data*

Characteristics	**Study sample (n=686)**		**2010 Census data (n=75,532,610)**	
	N	%	N	%
Gender				
Male	382	55.7	41,062,566	54.4
Female	304	44.3	34,470,044	45.6
Age				
$0 \leq$ age < 1	106	15.5	13,786,434	18.3
$1 \leq$ age < 2	141	20.6	15,657,955	20.7
$2 \leq$ age < 3	132	19.2	15,617,375	20.7
$3 \leq$ age < 4	159	23.2	15,250,805	20.2
$4 \leq$ age < 5	148	21.6	15,220,041	20.2
Nationality				
Han	607	88.5	66,938,873	88.6
Ethnic minorities	75	10.9	8,593,737	11.4
Missing	4	0.6	0	0.0

Notes: (1) *Data source: http://www.stats.gov.cn/tjsj/pcsj/rkpc/6rp/indexch.htm. (2) Due to rounding, percentages may not always add up to 100%.

However, this study has several limitations. First, the cross-sectional study design enables the examination of the association between grandparental caregiving and early childhood obesity but limits the power and confidence in determining a causal relationship; therefore a causal inference about living arrangement and early childhood obesity cannot be made from this study. Longitudinal data analysis should be applied in the future to further establish the causality. Second, the availability and completeness of some data from China Health and Nutrition Survey limited the scope of this study. Therefore this study failed to examine some key risk factors for early childhood obesity, e.g. physical activities, and breastfeeding practices. Third, although the China Health and Nutrition Survey is a national survey, cross-sectional sampling weights are not available due to the lack of sampling frame in the first place. Robust standard errors were calculated to make a more conservative estimation. Fourth, the confounders included in the regression model for analysis included group-level variables (e.g. individuals nested in families, and families nested in neighborhoods). While clustering effects were taken into account in the analysis, more advanced regression techniques such as hierarchical linear modeling would improve the precision of the parameter estimates for higher level variables. Lastly, this study did not include analysis of the neighborhood nutrition environment survey data which may provide important insights on the influence of the neighborhood food environment on the association between grandparental caregiving and early childhood obesity.

These limitations need to be addressed in the future studies in order to provide a more comprehensive and in-depth understanding of the role of grandparents in early childhood obesity and the mechanism in which three-generation families form a healthier environment for preschoolers in terms of early childhood obesity prevention.

REFERENCE

Bammann, K., Peplies, J., De Henauw, S., Hunsberger, M., Molnar, D., Moreno, L. A., . . . Siani, A. (2014). Early life course risk factors for childhood obesity: the IDEFICS case-control study. *PLoS One, 9*(2), e86914. doi:10.1371/journal.pone.0086914

Bronfenbrenner, U. (1994). Ecological models of human development. *Readings on the development of children, 2*, 37-43.

Chee, B. W. L. (2000). Eating snacks and biting pressure: only children in Beijing. In J. Jing (Ed.), *Feeding China's Little Emperors: Food, Children, and Social Change*.

Chen, F., Liu, G., & Mair, C. A. (2011). Intergenerational Ties in Context: Grandparents Caring for Grandchildren in China. *Soc Forces, 90*(2), 571-594. doi:10.1093/sf/sor012

Chen, S., Binns, C. W., & Zhang, Y. (2012). The importance of definition in diagnosing obesity: a review of studies of children in China. *Asia Pac J Public Health, 24*(2), 248-262. doi:10.1177/1010539512441617

CHNS. (2015). Data collection. *China Health and Nutrition Survey*. Retrieved from http://www.cpc.unc.edu/projects/china/about/design/datacoll

Cole, T. J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ, 320*(7244), 1240-1243.

Cox, R., Skouteris, H., Rutherford, L., Fuller-Tyszkiewicz, M., Dell' Aquila, D., & Hardy, L. L. (2012). Television viewing, television content, food intake, physical activity and body mass index: a cross-sectional study of preschool children aged 2-6 years. *Health Promot J Austr, 23*(1), 58-62.

Davis, M. M., McGonagle, K., Schoeni, R. F., & Stafford, F. (2008). Grandparental and parental obesity influences on childhood overweight: implications for primary care practice. *J Am Board Fam Med, 21*(6), 549-554. doi:10.3122/jabfm.2008.06.070140

de Onis, M., & Blössner, M. (2003). The World Health Organization global database on child growth and malnutrition: methodology and applications. *International Journal of Epidemiology, 32*(4), 518-526.

de Onis, M., & Habicht, J. P. (1996). Anthropometric reference data for international use: Recommendations from a World Health Organization Expert Committee. *American Journal of Clinical Nutrition, 64*(4), 650-658.

Formisano, A., Hunsberger, M., Bammann, K., Vanaelst, B., Molnar, D., Moreno, L. A., . . . Siani, A. (2014). Family structure and childhood obesity: results of the IDEFICS Project. *Public Health Nutr, 17*(10), 2307-2315. doi:10.1017/S1368980013002474

Fu, Q., & George, L. K. (2015). Socioeconomic determinants of childhood overweight and obesity in China: the long arm of institutional power. *Sociol Health Illn, 37*(6), 805-822. doi:10.1111/1467-9566.12234

Glanz, K., Rimer, B. K., & Viswanath, K. (2008). *Health behavior and health education: theory, research, and practice*: John Wiley & Sons.

Hawkins, S. S., Cole, T. J., & Law, C. (2009). An ecological systems approach to examining risk factors for early childhood overweight: findings from the UK Millennium Cohort Study. *J Epidemiol Community Health, 63*(2), 147-155. doi:10.1136/jech.2008.077917

Hawkins, S. S., & Law, C. (2006). A review of risk factors for overweight in preschool children: a policy perspective. *Int J Pediatr Obes, 1*(4), 195-209.

He, Q., Ding, Z. Y., Fong, D. Y., & Karlberg, J. (2000). Risk factors of obesity in preschool children in China: a population-based case--control study. *Int J Obes Relat Metab Disord, 24*(11), 1528-1536.

Health, N. I. o. C., & Network, H. D. E. C. C. R. (2000). Characteristics and quality of child care for toddlers and preschoolers. *Applied Developmental Science, 4*(3), 116-135.

IOM. (2011). *Early Childhood Obesity Prevention Policies*. Washington, DC: The National Academies Press.

Janjua, N. Z., Mahmood, B., Islam, M. A., & Goldenberg, R. L. (2012). Maternal and Early Childhood Risk Factors for Overweight and Obesity among Low-Income Predominantly Black Children at Age Five Years: A Prospective Cohort Study. *J Obes, 2012*, 457173. doi:10.1155/2012/457173

Ji, C. Y. (2005). Report on childhood obesity in China (1)--body mass index reference for screening overweight and obesity in Chinese school-age children. *Biomedical and environmental sciences, 18*(6), 390-400.

Ji, C. Y. (2007). Report on childhood obesity in China (4) prevalence and trends of overweight and obesity in Chinese urban school-age children and adolescents, 1985-2000. *Biomedical and environmental sciences, 20*(1), 1-10.

Ji, C. Y., & Cheng, T. O. (2008). Prevalence and geographic distribution of childhood obesity in China in 2005. *Int J Cardiol, 131*(1), 1-8.

Jiang, J., Rosenqvist, U., Wang, H., Greiner, T., Lian, G., & Sarkadi, A. (2007). Influence of grandparents on eating behaviors of young children in Chinese three-generation families. *Appetite, 48*(3), 377-383. doi:10.1016/j.appet.2006.10.004

Jiang, J., Rosenqvist, U., Wang, H., Greiner, T., Ma, Y., & Toschke, A. M. (2006). Risk factors for overweight in 2- to 6-year-old children in Beijing, China. *Int J Pediatr Obes, 1*(2), 103-108.

Kim, I. K., Lee, H. J., Kang, J. H., & Song, J. (2010). Effect of parental overweight and serum leptin levels on the manifestation of overweight in 7-year-old Korean children. *Public Health Nutr, 13*(3), 384-392. doi:10.1017/S1368980009992114

Li, B., Adab, P., & Cheng, K. K. (2014). Family and neighborhood correlates of overweight and obesogenic behaviors among Chinese children. *International journal of behavioral medicine, 21*(4), 700-709.

Li, B., Adab, P., & Cheng, K. K. (2015). The role of grandparents in childhood obesity in China - evidence from a mixed methods study. *Int J Behav Nutr Phys Act, 12*(1), 91. doi:10.1186/s12966-015-0251-z

Li, N., Liu, E., Sun, S., Guo, J., Pan, L., Wang, P., . . . Hu, G. (2014). Birth weight and overweight or obesity risk in children under 3 years in China. *Am J Hum Biol, 26*(3), 331-336. doi:10.1002/ajhb.22506

Lin, Q., Adab, P., Hemming, K., Yang, L. N., Qin, H., Li, M. Z., . . . Chen, J. H. (2015). Health allowance for improving the nutritional status and development of 3-5-year-old left-behind children in poor rural areas of China: study protocol for a cluster randomised trial. *Trials, 16*. doi:ARTN 36110.1186/s13063-015-0897-5

Lindberg, L., Ek, A., Nyman, J., Marcus, C., Ulijaszek, S., & Nowicka, P. (2015). Low grandparental social support combined with low parental socioeconomic status is closely associated with obesity in preschool-aged children: a pilot study. *Pediatr Obes*. doi:10.1111/ijpo.12049

Liu, J., Sekine, M., Tatsuse, T., Hamanishi, S., Fujimura, Y., & Zheng, X. (2014). Family history of hypertension and the risk of overweight in Japanese children: results from the Toyama Birth Cohort Study. *J Epidemiol, 24*(4), 304-311.

Lobstein, T., Baur, L., & Uauy, R. (2004). Obesity in children and young people: a crisis in public health. *Obesity reviews : an official journal of the International Association for the Study of Obesity, 5 Suppl 1*, 4-104. doi:10.1111/j.1467-789X.2004.00133.x

Luo, J., & Hu, F. B. (2002). Time trends of obesity in pre-school children in China from 1989 to 1997. *Int J Obes Relat Metab Disord, 26*(4), 553-558.

Luo, J. Y., Peng, X. C., Zong, R., Yao, K. B., Hu, R. S., Du, Q. Y., . . . Zhu, M. Y. (2008). The status of care and nutrition of 774 left-behind children in rural areas in China. *Public Health Reports, 123*(3), 382-389.

Misra, A. (2003). Revisions of cutoffs of body mass index to define overweight and obesity are needed for the Asian-ethnic groups. *Int J Obes Relat Metab Disord, 27*(11), 1294-1296. doi:10.1038/sj.ijo.0802412

Nader, P. R., O'Brien, M., Houts, R., Bradley, R., Belsky, J., Crosnoe, R., . . . Human Development Early Child Care Research, N. (2006). Identifying risk for obesity in early childhood. *Pediatrics, 118*(3), e594-601. doi:10.1542/peds.2005-2801

Pearce, A., Li, L., Abbas, J., Ferguson, B., Graham, H., Law, C., & Millennium Cohort Study Child Health, G. (2010). Is childcare associated with the risk of overweight and obesity in the early years? Findings from the UK Millennium Cohort Study. *Int J Obes (Lond), 34*(7), 1160-1168. doi:10.1038/ijo.2010.15

Pediatrics, C. I. o. (2009). [Growth standardized values and curves based on weight for length/height, body mass index for Chinese children under 7 years of age]. *Chinese Journal of Pediatrics, 47*(4), 281-285.

Popkin, B. M. (2001). The nutrition transition and obesity in the developing world. *J Nutr, 131*(3), 871S-873S.

Popkin, B. M., Du, S., Zhai, F., & Zhang, B. (2010). Cohort Profile: The China Health and Nutrition Survey--monitoring and understanding socio-economic and health change in China, 1989-2011. *Int J Epidemiol, 39*(6), 1435-1440. doi:10.1093/ije/dyp322

Pulgaron, E. R., Patino-Fernandez, A. M., Sanchez, J., Carrillo, A., & Delamater, A. M. (2013). Hispanic children and the obesity epidemic: exploring the role of abuelas. *Fam Syst Health, 31*(3), 274-279. doi:10.1037/a0034208

Reilly, J. J. (2002). Assessment of childhood obesity: national reference data or international approach? *Obesity Research, 10*(8), 838-840. doi:10.1038/oby.2002.113

Reilly, J. J., Armstrong, J., Dorosty, A. R., Emmett, P. M., Ness, A., Rogers, I., . . . Children Study, T. (2005). Early life risk factors for obesity in childhood: cohort study. *BMJ, 330*(7504), 1357. doi:10.1136/bmj.38470.670903.E0

Robinson, S. M., Crozier, S. R., Harvey, N. C., Barton, B. D., Law, C. M., Godfrey, K. M., . . . Inskip, H. M. (2015). Modifiable early-life risk factors for childhood adiposity and overweight: an analysis of their combined impact and potential for prevention. *Am J Clin Nutr, 101*(2), 368-375. doi:10.3945/ajcn.114.094268

Rolland-Cachera, M. F. (2011). Childhood obesity: current definitions and recommendations for their use. *Int J Pediatr Obes, 6*(5-6), 325-331. doi:10.3109/17477166.2011.607458

Skouteris, H., McCabe, M., Swinburn, B., Newgreen, V., Sacher, P., & Chadwick, P. (2011). Parental influence and obesity prevention in pre-schoolers: a systematic review of interventions. *Obesity Reviews, 12*(5), 315-328. doi:DOI 10.1111/j.1467-789X.2010.00751.x

Suglia, S. F., Duarte, C. S., Chambers, E. C., & Boynton-Jarrett, R. (2013). Social and behavioral risk factors for obesity in early childhood. *J Dev Behav Pediatr, 34*(8), 549-556. doi:10.1097/DBP.0b013e3182a509c0

Tan, C., Luo, J. Y., Zong, R., Fu, C. H., Zhang, L. L., Mou, J. S., & Duan, D. H. (2010). Nutrition knowledge, attitudes, behaviours and the influencing factors among non-parent caregivers of rural left-behind children under 7 years old in China. *Public Health Nutrition, 13*(10), 1663-1668. doi:10.1017/S1368980010000078

Taveras, E. M., Gillman, M. W., Kleinman, K., Rich-Edwards, J. W., & Rifas-Shiman, S. L. (2010). Racial/ethnic differences in early-life risk factors for childhood obesity. *Pediatrics, 125*(4), 686-695. doi:10.1542/peds.2009-2100

UNICEF. (2014). *Levels and trends in child malnutrition: UNICEF-WHO-The World Bank Joint Child Malnutrition Estimates*. Retrieved from http://www.who.int/nutgrowthdb/summary_jme_2013.pdf?ua=1

Veldhuis, L., Vogel, I., Renders, C. M., van Rossem, L., Oenema, A., HiraSing, R. A., & Raat, H. (2012). Behavioral risk factors for overweight in early childhood; the 'Be active, eat right' study. *Int J Behav Nutr Phys Act, 9*, 74. doi:10.1186/1479-5868-9-74

Velez, J. C., Fitzpatrick, A. L., Barbosa, C. I., Diaz, M., Urzua, M., & Andrade, A. H. (2008). Nutritional status and obesity in children and young adults with disabilities in Punta Arenas, Patagonia, Chile. *Int J Rehabil Res, 31*(4), 305-313. doi:10.1097/MRR.0b013e3282fb7d3c

Wang, Y., & Chen, H. J. (2012). Use of percentiles and z-scores in anthropometry *Handbook of Anthropometry* (pp. 29-48): Springer.

Wang, Y., & Lobstein, T. (2006). Worldwide trends in childhood overweight and obesity. *International Journal of Pediatric Obesity, 1*(1), 11-25. doi:10.1080/17477160600586747

Watanabe, E., Lee, J. S., & Kawakubo, K. (2011). Associations of maternal employment and three-generation families with pre-school children's overweight and obesity in Japan. *Int J Obes (Lond), 35*(7), 945-952. doi:10.1038/ijo.2011.82

WHO. (1995). *Physical status: the use and interpretation of anthropometry: report of a WHO Expert Committee*. Retrieved from Geneva: http://www.who.int/childgrowth/publications/physical_status/en/

WHO. (2006). *WHO child growth standards : length/height-for-age, weight-for-age, weight-for-length, weight-forheight and body mass index-for-age : methods and development*. Retrieved from France: http://www.who.int/childgrowth/standards/technical_report/en/

WHO. (2013). The World Health Organization's global target for reducing childhood stunting by 2025: rationale and proposed actions. *Maternal and Child Nutrition, 9*, 6-26. doi:10.1111/mcn.12075

WHO. (2014). *Global nutrition targets 2025: childhood overweight policy brief (WHO/NMH/NHD/14.6)*. Retrieved from Geneva: http://apps.who.int/iris/bitstream/10665/149021/2/WHO_NMH_NHD_14.6_eng.pdf?ua=1.

WHO. (2015a). Global strategy on diet, physical activity, and health: childhood overweight and obesity. Retrieved from http://www.who.int/dietphysicalactivity/childhood/en/

WHO. (2015b). What is overweight and obesity? Retrieved from http://www.who.int/dietphysicalactivity/childhood_what/en/

Wu, Y. (2006). Overweight and obesity in China. *BMJ, 333*(7564), 362-363. doi:10.1136/bmj.333.7564.362

Wu, Y. F., Ma, G. S., Hu, Y. H., Li, Y. P., Li, X., Cui, Z. H., . . . Kong, L. Z. (2005). [The current prevalence status of body overweight and obesity in China: data from the China National Nutrition and Health Survey]. *Zhonghua Yu Fang Yi Xue Za Zhi, 39*(5), 316-320.

Zhang, B., Zhai, F. Y., Du, S. F., & Popkin, B. M. (2014). The China Health and Nutrition Survey, 1989-2011. *Obesity reviews : an official journal of the International Association for the Study of Obesity, 15 Suppl 1*, 2-7. doi:10.1111/obr.12119