Early Childhood and Concurrent Factors associated with Obesity at age 8 in Vietnamese children in the Young Lives Cohort Study

By

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Table of Contents

Dedication

This thesis is dedicated to my parents, family, and partner for their unconditional love and support. Thank you mom and dad for all your sacrifices so that I could have the opportunities to achieve higher education and pursue my dreams. Thank you Andy for all the wonderful meals you cook for us and for always being my biggest cheerleader.

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CHAPTER 1: LITERATURE REVIEW

Background & Significance

a. Childhood obesity

i. Defining overweight and obesity

According to the World Health Organization (WHO) and the International Obesity Task Force (IOTF), overweight and obesity are defined as abnormal or excessive weight gain that negatively influences health [1]. Body mass index (BMI) is the most commonly used anthropometric measurement for body fat and is used to categorize overweight and obesity. BMI is a simple index of weight-for-height and can be calculated by dividing the weight in kilograms by the square of the height in meters.

According to the WHO, The international classification and BMI cut offs for adult underweight, overweight, and obesity are less controversial than that for children's BMI cut offs. The normal range for adults is BMI is 18.5-24.99 kg/m^2. For adults, the BMI cut off for overweight is BMI 25-29.9 kg/m^2 and obese is 30 kg/m^2 or higher [2].

Children's criteria for childhood overweight and obesity can be inconsistent between the different research institutions [3]. This is mainly due to the fact that as children grow, they gain weight naturally as a process of development. However, defining when their weight gain becomes significant in terms of BMI can be tricky and has changed over the years.

The cut-off points for the WHO applies to centile curves for children aged 2-17 for overweight and obesity are BMI>85% and BMI>95%, respectively [4]. Meanwhile, instead of centile curves, the IOTF adopted BMI cut off points that are similar to that used for adults [5]. The resulting BMI cut off adopted by the IOTF for children aged 2-18 for overweight and obese are approximately 25-29.9 kg/m^2 and 30 kg/m^2 or higher. Before 2010, the Centers for Disease Control and Prevention (CDC) use centile curves for children age 2-20 that defined BMI>85% as at risk for overweight and BMI>95% as overweight. After 2010, the CDC changed the definition to BMI>85% on centile curves as overweight and BMI>95% as obese [6]. The changes in definitions of BMI and the inconsistency between different research institutions make it more difficult to estimate the prevalence of international childhood overweight and obesity. Furthermore, it also makes it difficult to compare across studies that have used different cut off points [5].

In 1998, Pietrobelli et al explored the validity of using body mass index as a measure of adiposity in children and adolescents and found that age was a significant covariate in all regression models. The study supported the use of body mass index in groups of children and adolescents, but did warn the limitations when comparing body mass index across groups of different age [7]. In a more recent review from 2005, Must and Anderson suggests that only the International Obesity Task Force (IOTF) reference provides the smoothest transition from child/adolescent to adult definition of overweight and obesity. The IOTF reference defines as the BMI-for-age that passes through a BMI of 25 kg/m^2. For research applications, Must and Anderson's review provide evidence that BMI z-scores can be appropriately used to compare between group means and to model relative weight trajectories longitudinally [8]. However, Must and Anderson did make a note that the BMI cut-off is different for people of Asian descent. The IOTF's body mass index cut offs by age from 2-18 years notes that the unofficial cut-off for Asians is 23 kg/m^2 for overweight and 27 kg/m^2 for obesity [4]. These unofficial cut-offs are 2 BMI points lower the normal cut-off points for overweight and obesity. The unofficial cut-offs

were made to address many studies from Asia that have shown diabetes risk has increased remarkably for populations of Asian origin at a mean BMI that is significantly lower than the currently defined at-risk levels [9].

According to the World Health Organization, the definition of overweight and obesity changes at age 5. From birth to age 5, the WHO's cut-off points are BMI for age Z score >2+ and >3+ for overweight and obesity, respectively [10]. Whereas, the reference range for age 5-19 is classified at the cut-off point of >1+ SD and >2+ SD for overweight and obese categories, respectively [2]. Though IOTF and WHO may use different terminology, the BMI cut offs are similar in that they are both based on BMI relative to a reference distribution of BMI for sex and age.

It is important to note that BMI Z scores for age is not a diagnostic tool when used in research, but it can be used as a screening tool for degree of body adiposity and health risks. In addition, a review in 2013 by Javed et al found that using body mass index for age Z score cut-offs to identify obesity in children and adolescents has high specificity but low sensitivity to detect excess adiposity, which failed to identify over a quarter of the children with excess body fat percentage in the 37 studies that were examined [11]. Since the BMI cut-off points may have low sensitivity, future research efforts should also consider studying the groups at risk for overweight and obesity.

Historically, nutrition and health research in low and middle-income countries had been focused solely on underweight and stunting. The United Nations established Millennium Development Goals in September 2000 to help address extreme poverty, hunger, and diseases in developing nations by 2015. However, childhood obesity was not an area of interest then as these goals were more focused on malnutrition as defined by lack of sufficient nutrients [12].

In 2013, the Nutrition for Growth Summit called for a Global Nutrition Report. The first report redefined malnutrition to include both underweight and overweight children. The Global Nutrition Report calls for more research and governmental investment in preventing childhood obesity in low and middle-income countries as they are now facing a more complex nutrition problem that includes both underweight and overweight [13].

ii. The health impacts of childhood obesity

In the last decade, childhood obesity has emerged as a global public health crisis. It is estimated that about 10% of school-aged children worldwide are overweight or obese, which puts them at higher risk for developing chronic diseases [14]. Early childhood obesity are linked to chronic health problems in childhood and significantly increases the risk for chronic health problems in adulthood. These chronic health conditions include (but are not limited to): fatty liver disease, sleep apnea, Type 2 diabetes, asthma, hepatic steatosis, cardiovascular disease, high cholesterol, cholelithiasis, glucose intolerance, insulin resistance, skin conditions, menstrual abnormalities, impaired balance, and orthopedic problems [15].

Overweight that begins before 8 years of age is associated with an average higher BMI of 41 kg/m^2 in adulthood as compared to adulthood onset of obesity that has a BMI of 35 kg/m^2 [16]. In addition to its association with higher BMI in later life, childhood obesity before age 8 is also associated with increased risk of early complications from diabetes and cardiovascular disease [17].

Approximately 60% of 5 to 10 year old overweight children develop at least one physiological cardiovascular disease risk factor and it has also been estimated that at least one third of the children in the United States will develop diabetes at some point in their lives [18] [19].

Childhood obesity is a big risk factor for early onset of metabolic disease, cardiovascular disease, type 2 diabetes, and some types of cancer [20].

Until recently, the majority of cases of diabetes mellitus in children and adolescents were type 1 immune-mediated disease [21]. Over the past two decades, there has been a dramatic increase in type 2 diabetes amongst children. Obesity is a major risk factor for chronic and noncommunicable diseases through the pathophysiology of insulin resistance or metabolic syndrome. Metabolic syndrome involves a state of hyperinsulinemia, hypertension, hyperlipidemia, type 2 diabetes, and an increased risk for atherosclerotic cardiovascular disease [22]. Insulin resistance in childhood and adiposity may lead to early vascular damage and other future health complications such as non-fatty liver disease [23]. In addition, there is a significant increased in risk of premature mortality with child and adolescent overweight and obesity associated with development of noncommunicable diseases in adulthood [24].

iii. Childhood obesity trends in low and middle-income countries

In 1997, the WHO Expert Consultation on Obesity brought up the issue of an escalating epidemic of obesity that put the populations of most countries at risk for non- communicable disease [25]. The most notable of overweight and obesity are in the low and middle-income countries. The spread to less developed countries first started with urban middle aged adults, but is now radiating to semi-urban and rural areas for younger age groups [26]. Globally in 2010, the number of overweight children under five is estimated to be over 42 million. About 35% of these children are living in developing countries [20].

In high-income countries, obesity disproportionately affects people of lower socioeconomic status [27]. On the other hand, low and middle-income countries, the more affluent and/or those in higher education attainment tend to be more likely to be overweight or obese [28]. In addition, obesity in children appears to be predominantly associated with higher socioeconomic status in both low- and middle-income countries [29]. This conclusion was unanimous amongst 11 studies that were reviewed in Dinsa's systematic review. The distinction of low income, middle income, and high-income countries is based on the World Bank's classification: low income is defined as gross national income (GNI) per capita below US $1,000, middle income is defined as GNI per capita greater than US $1,000 to $12,275; high income is defined as GNI per capita greater than US $12,275 [30].

Many low and middle-income countries bear the weight of the "nutrition paradox," in which childhood underweight and overweight both exist. Doak and Popkin in 2005 examined the prevalence of households with underweight and overweight persons found that in six countries studied, 22-66% of the household with an underweight person also had an overweight person. In addition, the countries with the highest prevalence of the dual burden of malnutrition and overweight/obesity were those in the middle range of gross national product. Interestingly, the study found that the prevalence of the dual burden is not significant in Vietnam since the country is at the earliest stages of the nutrition transition [31]. Notably, Doak and colleagues used household surveys from 1992 to 1993. This may have been so early in the transition that the prevalence of overweight and obesity is not yet noticeable in Vietnam.

In most Asian countries, the prevalence of overweight and obesity has increased many fold in the past few decades, though the magnitude varies between countries [31]. In 2008, Malaysia had the highest obesity prevalence in Southeast Asia at 14% in the Southeast Asia region with Thailand occupying the second spot at 8.8%. Meanwhile, Vietnam and India had the lowest rates at 1.7% and 1.9%, respectively. Compared with the United States, which has a

prevalence of obesity at 33%, these numbers may seem unremarkable. However, the overweight and obesity rates in the US have almost stabilized over the past five years, while the rates are increasing more rapidly in Asian countries. Between 1980 to 2013, China's overweight and obesity prevalence increased from 11.3% to 27.9% and from 5.7% to 18.8% in individuals under 20 years of age [32]. In Malaysia, the prevalence of obesity amongst adults increased from 4.4% in 1996 to 14% in 2006 [33]. Similarly in Vietnam, overweight and obesity prevalence among adults more than doubled from 2% to 5.7% in 1992 to 2002 [34].

Data from nationally representative cross-sectional surveys from developing countries have shown a high prevalence of overweight in preschool children less than 5 years of age: Uzbekistan at 14.4% (1996), Algeria at 9.2% (1995), Thailand at 1.2% (1987), Bangladesh at 1.1% (1996-1997), Oman at 0.9% (1994-1995), the Philippines at 0.8% (1993), Vietnam at 0.7% (1998), and Nepal at 0.5% (1996). The study found that the countries with the highest prevalence of overweight are mainly located in Middle East, North Africa, and Latin America [10]. The prevalence of obesity amongst preschool children less than 5 years of age in Asia does not appear to be a public health issue as the prevalence is still fairly low [35]. However, most studies on prevalence used data from the 1990s, which is now over 20 years old before the nutrition transition was apparent in Southeast Asia. There is a need for more current analysis of the prevalence of overweight and obesity amongst developing countries with rapid increase in adult obesity.

For school-aged children and adolescents, the estimated global prevalence of overweight and obesity in children aged 5-19 is 10% with a range of 5.7% in Pakistan to over 40% in Mexico [36] [37].The prevalence for overweight and obesity in China is 13.8% analyzed from the National Nutrition and Health Survey in 2002 [38]. As for other countries in Asia, there are few representative reports available on the national prevalence of obesity amongst Asian children since most studies are conducted in a selected region of the country.

Though overweight and obesity prevalence is lower in most developing countries as compared to more developed countries, the trend of obesity is rising much quicker in developing countries. Most of this data is derived from studies from national surveys looking at obesity rates in adults. There is a lack of up-to-date data that is nationally representative for most developing countries including Vietnam on the prevalence and incidence obesity amongst children less than 20 years of age. Regardless, the rising trend of overweight and obesity in developing countries needs to be addressed as it may lead to consequently higher incidence of non-communicable diseases in these countries that are carrying the burden of both underweight and overweight malnutrition.

Causes of childhood obesity at country level

a. The Nutrition Transition

i. The nutrition transition

Nutrition transition is the shift in dietary consumption and energy expenditure that is correlated with economic, demographic, and epidemiological changes [39]. The nutrition transition model was first proposed in 1993 by Popkin as a framework to study the emerging dietary transition of developing countries from a traditional diet high in cereal and fiber to a more "westernized" diet high in sugars, fats, and proteins. This framework has since been the most used and cited in nutrition transition research [40].

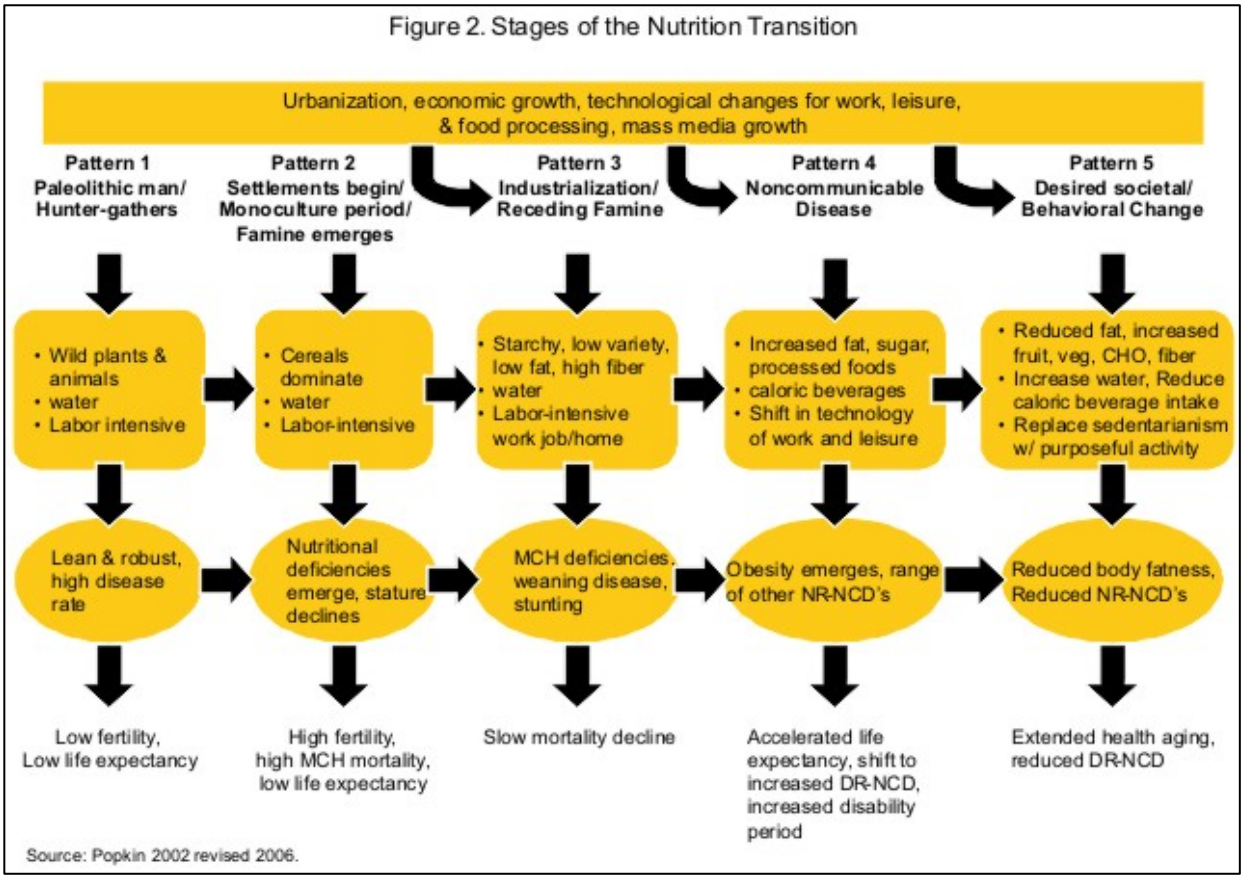
Popkin builds on two historical concepts in his proposed framework: the demographic transition and the epidemiological transition. The demographic transition explains the shift from

a pattern of high fertility and high mortality to low fertility and low mortality, which is typically seen as a country becomes industrialized. The epidemiological transition, first proposed by Omran in 1971, is the shift from "a pattern of high prevalence of infectious diseases associated with malnutrition, periodic famine, and poor environmental sanitation to a pattern of high prevalence in chronic and degenerative diseases associated with urban-industrial lifestyles [40]."

Using these two historical concepts as a foundation of societal transition, Popkin summarizes the nutrition transition into five broad patterns. The first pattern is characterized by hunter-gathers whose diets are high in wild plants and animals. The second pattern is defined by famine, which is marked by a scarcity and reduced diversity of food supply. The third is receding famine in which fruits, vegetables, starch, and animal protein increases. The fourth pattern is one of degenerative diseases with onset by a diet high in total fat, cholesterol, and sugar. The final pattern is characterized by behavioral change reflective of a desire to delay degenerative diseases [39].

Though the categories proposed in the nutrition transition model are broad, they can serve as a useful framework to understand the current state of dietary change and food consumption in developing countries and the health implications of this change [41]. Of particular interest are rapidly developing economies that are rapidly shifting towards a more westernized diet marked by increased intake of high levels of proteins, fats, and sugars.

Figure 1. Popkin's stages of the nutrition transition.[39]



ii. The nutrition transition in rapidly developing economies

The global dietary change appears to be shifting towards a diet dominated by higher intakes of animal and partially hydrogenated fats and lower intakes of fiber leading to an increase in the burden global burden of non-communicable diseases such as childhood obesity. In addition, this change in diet is also associated with a decrease in physical activity and weight gain [39]. Nutrition data from the World Health Organization and the Food and Agriculture Organization of the United Nations also reinforces the nutrition transition trend of increased caloric intake of high levels of protein, fats, and sugars [42]. The nutrition transition is most rapidly changing in countries with rapid economic growth and in low and middle-income countries such as China, Brazil, and Peru[42]. The negative health effects have been most pronounced and studied in these countries as they have gone through the nutrition shift in the early 1980s-90s. Meanwhile, the rate of overweight and obesity in these countries has been increasing with this change in diet.

In China, the economic shift in import regulations led to excessive use of oils by all social classes. Consumption of eggs, poultry, beef, and pork has also increased rapidly in China[43]. Similarly, in the last ten years, Vietnam is starting to experience a similar nutrition shift as its economy rapidly develops [44].

These dietary changes were not recognized in low and middle-income countries until diabetes, hypertension, and obesity became more prevalent worldwide. With increasing research on global obesity, the nutrition shift has been indicated as the main driver for this pandemic. In 2008, the prevalence of overweight and obesity were estimated to be around 1.5 billion adults. This number of overweight adults is predicted to rise to 2.16 billion globally, and 1.2 billion will be obese by 2030 [45].

iii) The nutrition transition in Vietnam

In the forty years after the end of World War II, Vietnam was the focal point of the struggle for and against colonialism and the war between capitalism and socialism [46]. The Vietnam War, or *Chiến tranh Việt Nam*, between the North Vietnamese and the South Vietnamese governments started in 1955 and ended on April 30, 1975 when the Southern government surrendered to the Communist North. Though the country was at this time united under Communism, the country was ruined economically. Vietnam's infrastructure and its farmland were polluted by chemical warfare and bombings [47 48]. In 1975, it was one of the poorest countries. In addition, the Vietnamese people who survived the war were left tormented by the psychological trauma and physiological effects of poverty and malnutrition. After the war, Vietnam's reunification efforts and policies under Communist governance failed to improve its economy [47].

In the 1980s, Vietnam's government began to focus their attention on market reforms and economic policies. Though it was a Communist state, it moved from a centrally government controlled economy to a market-oriented by opening its economic policies to the rest of the world. The most notable reform known as the *Doi Moi* economic reforms of 1986 helped Vietnam shift towards a globally oriented market economy. Since then, the country's economy has been growing rapidly on a yearly average of 7% gross domestic product from 1991-2007 [30]. In addition, Vietnam became a member of the Association of Southeast Asian Nations in 1995 and a member of the World Trade Organization in 2007. Soon after, its foreign direct investment reached an all-time high of US $71.7 billion in 2008 [49]. With Vietnam's economic success, its

neighboring countries including Laos, Cambodia, and Myanmar have enacted many macroeconomic reforms similar to that of the *Doi Moi* reforms [50].

Foreign direct investment is an investment by an enterprise from one country into another. Foreign direct investment in developing countries like Vietnam has grown faster than gross domestic product or trade. Specifically, foreign direct investment in the food processing industry enabled the development, distribution, and consumption of highly processed foods in developing countries [51].

There is a large body of evidence that indicates that indicates many Asian countries with fast growing economies, like Vietnam, currently face a double burden of malnutrition—underweight and overweight [52]. Arguably, this double burden has been driven by the nutrition transition, which is fueled by economic growth and foreign direct investments. Traditional Vietnamese diet is high in carbohydrates and vegetables while low in animal fat and proteins [53]. This contributes to the population's low in energy intake [54]. However, the diet in Vietnam has changed remarkably. There is an increase of animal sourced foods high in proteins, fats, and oils [55]. This nutrition shift is however not homogenous across all regions of Vietnam as higher BMI is correlated with higher social economic status and living in more urbanized areas [56].

The nutrition transition experienced in growing economies today compared to the transition experienced in the past is more rapid due to globalization and technology [57]. Thus the rise and concern for childhood overweight and obesity and consequently non-communicable diseases must be urgently addressed [57].

Causes of childhood obesity at household/community level

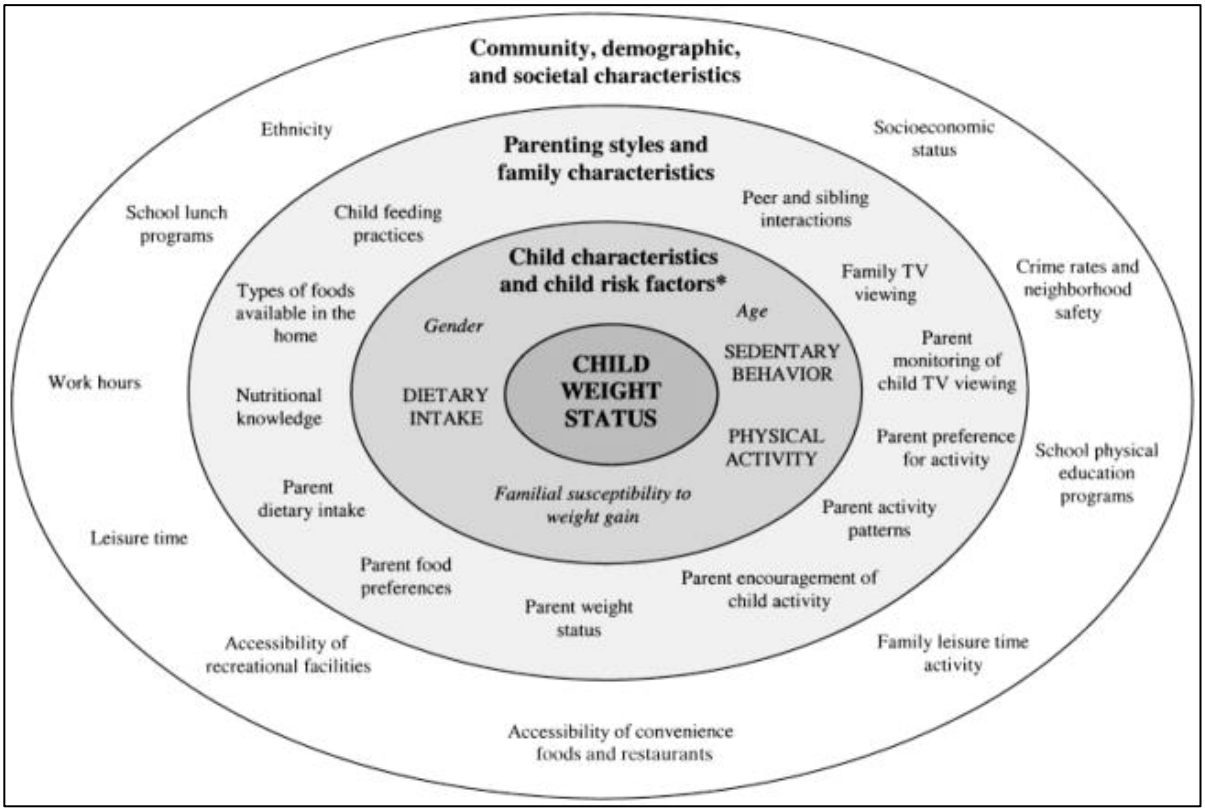
a. Ecological Framework

i. Ecological model of childhood obesity

Since childhood obesity has become a major public health concern globally, it is also well recognized that the causes of childhood obesity are complex and multifactorial [58]. One model that has been often referenced and used in childhood obesity studies is the ecological model for predictors of childhood overweight proposed by Davidson and Birch in 2001 [59]. This model is based on the ecological systems theory that conceptualizes human development from an interactive network between the individual and his/her environment and community. According to ecological systems theory, change in an individual's characteristic or health behavior cannot be explained without the consideration of the individual's ecologic niche [60].

Using this model to explain childhood overweight and obesity, the child's weight status (i.e. BMI) is affected by the child's characteristics and child behaviors, parenting styles and family characteristics, and the child's community and societal characteristics. The interaction between these domains that makes up the child's ecologic niche will affect the child's weight status [59]. This model helps conceptualize the factors that affect a child's risk for overweight and obesity.

Figure 2. Davison and Birch's ecological model of childhood obesity [59]



a. Risk factors associated with childhood obesity using the ecological model

Using the Davison and Birch's ecological model of childhood obesity, we can examine the different factors in a child's ecologic niche to evaluate the risk factors and the interactions between these factors that may be associated with childhood overweight and adiposity.

i. Child characteristics and risk factors

Genetics

Based on twin and adoption studies, there is evidence that genetic factors have a strong effect on the variations in body mass index at all ages [61]. Furthermore, Silventoinen and colleagues found that genetics seems to play a bigger role after adolescence [62]. In another systematic review exploring the relationship between obesigenic alleles and childhood predictors of adult obesity, Parsons and colleagues summarized the findings that parent obesity is an important factor in predicting adult obesity of offspring, and that offspring of obese parents who themselves are fatter in childhood are at a higher risk [63].

Birth weight, infant size and growth

A review of 20 studies found a positive association between birth-weight and obesity in infancy and childhood [64]. However, there have been noted inconsistencies in the relation between birth-weight and childhood obesity as studies have also shown that infants who experienced growth restriction in utero, as indicated by their lower birth weight, tend to gain weight, or "catch up" more rapidly during the early post natal period [65] [66]. This may lead to central fat deposition and greater insulin resistance. Despite these inconsistencies, high levels of birth

weight, defined as birth weight equal to or greater than 3,500 grams were associated with increased odds of obesity among 9-11 year old children in 12 countries [67].

Physical activity

Janssen et al. evaluated the association with overweight and obesity in 34 countries mainly from North America and Europe and found that amount of time spent on physical activity was positively associated with lower body mass index in 29 out of 33 countries [68]. In addition, the review also found a positive relationship between television viewing time and increased body mass index in 22 out of 34 countries. The odds of being overweight were greater for children with increased television-viewing time [68]. In a more recent systematic review published in 2011 using cross-sectional studies in the past decade, researchers found evidence that supported Janssen's findings that physical activity was negatively associated with child weight while sedentary behaviors, such as television-viewing, were positively related to childhood adiposity[69].

Sleep Durations

A systematic review that explored the association between sleep duration and weight gain using 17 observational studies found that children with shorter sleep duration had a 58% higher risk for overweight and obesity [70]. Furthermore, children with the shortest sleep duration had an even higher risk compared to children who had longer sleep duration. Boys had a stronger inverse association than girls (OR 2.50 versus 1.24) [71]. A recent studied also supported this evidence with notable findings that daily sleep duration of less than 12 hours during infancy appears to be a risk factor for overweight and adiposity in pre-school aged children [72].

Dietary Intake/patterns

Current research suggests that there is a positive association between greater intakes of sugar-sweetened beverages and weight gain in both children and adults [73]. In addition, beverages with added sugar appears to be associated with overweight and obesity in pre-school children [74]. Due to the nature of dietary intake research often relying on 24-hour diet recall surveys, there is a lack of high-quality prospective evidence in the association between daily dietary intake and childhood obesity. However, a review of observational studies shows that there is strong evidence that high-energy intake in early infancy and high consumption of excessive animal fats and sugars is associated with adiposity risk [1].

ii. Maternal factors & Family characteristics

Prenatal Exposure

In a systematic review by Huang and colleagues, four out of 6 studies found a higher prevalence of overweight or obesity associated with pre-gestational and gestational diabetes [75]. There were significant association between prenatal exposure to maternal smoking and childhood overweight and obesity [76]. Maternal malnutrition early on in pregnancy can also cause a programing of structural and functional abnormalities of various endocrine systems leading to increased adiposity for children [77].

Infant Feeding

Monsanta et al's systematic review of breastfeeding and its association with childhood obesity found that breastfeeding had a protective effect against childhood obesity with the pooled

adjusted OR 0.78 [70]. Furthermore, Owen's systematic review reveals that duration of breastfeeding was inversely associated with the risk of overweight [78].

Family Characteristics

Research shows various positive correlations between children's and parent's weights status, dietary intake, food preference, and activity patterns.

- **Weight status:** Various studies have suggests that there is a positive correlation between parent's body mass index and their children's body mass index in which a significant risk factor for obesity in children up to 12 years of age is parent's adiposity [79] [80]. Obese mothers are four times more likely to have obese children with additive risk if the father is also obese [81].
- **Dietary pattern:** The Framingham Children's Study found that parents' eating habits have an impact on the nutrient intake of their preschool children. This correlation is higher between mothers and children than between fathers and children [82]. Using the Framingham Children's Study data, another study found similar correlation between parental nutrient intake and children's development of obesity in children 3-5 years of age. Hood et al report findings that suggest parents who show high levels of disinhibited eating may contribute to development of excess body fat in their children [83]. In another study, Laskarzewski and colleagues evaluated the interrelationships between nutrient intakes of parents and children ages 6 to 19 and found that the proportion of parental nutrient intake varied from a low of 23% for parent-child cholesterol intakes to a high of 97% for carbohydrate intake [84].
- **Food preferences:** Parenting styles play a crucial role in children's food preferences. Specifically, using food as a reward such as giving children sweets as a reward decreases the preference for other types of foods [85] [86]. In this way, parents may also condition to children to associating sugary foods with a more positivity than vegetables and other healthier options.
- **Physical activity patterns:** Parent influences accounts for 20% of variance in physical activity, 26% variance in attraction to physical activity, and 28% in perceptions of competence [87]. Parent's inactivity is also a strong positive indicator of child inactivity [88].

iii. Community characteristics

Social economic status

In high-income countries like the United States, higher economic status in childhood is associated with a lower risk of childhood obesity [89] [74] [90]. Unlike high-income countries, there is a strong positive association between social economic status and increase in body mass index for low and middle-income countries [91].

The built environment

The built environment where the child lives plays an important role in the accessibility of food and safe areas for time to spend on physical activity. A systematic review exploring the correlation between local food environment and obesity found that supermarket availability is more likely to be negatively associated with obesity in 10 different studies [92]. In the same review, the researchers also found that grocery store availability was more likely to be positively associated with obesity in 5 different studies. These two findings seems to contradict each other

but it may be the availability of vegetables and fruits that shows up as differences in the directions of association between grocery stores and supermarkets with childhood obesity.

Neighborhood walkability as measured by structural components such as road safety, street connectivity, and residential density can also influence childhood obesity. Spence explored the influence of neighborhood design on overweight amongst preschool children found that better walkability score had protective effects against childhood obesity [93]. Galvez's review of studies exploring neighborhood safety and its association with childhood obesity showed that four studies found evidence that perceived safety was related to increased physical activity such as time spent playing outdoors in 10-12 years old, being active in the streets in 5-11 years old, and walking to shops in 5-18 year olds [94].

b. Current research in risk factors associated in childhood obesity in Vietnam

The majority of literature in childhood obesity and the associated determinants was studied in high-income countries since childhood obesity is a relatively new phenomenon in low-income and middle-income countries. Overweight and obesity have a reached an epidemic level in many Asian countries that puts them at risk for metabolic related disorders such as diabetes, hypertension, and cardiovascular disease. Currently, India has the highest number of people with diabetes in the world with China closely behind in second place [95]. The prevalence of obesity varies widely between different countries with developed countries like Japan, Singapore, Malaysia, and Hong Kong in more advanced stages of this epidemic. Other countries like Vietnam and Indonesia are in the early stages of development of this epidemic [96]. Though this issue has been written about, there lacks systematic national data on prevalence of obesity from Asian countries. Furthermore, there have only been a handful of studies on childhood obesity for both prevalence and risk factors in Southeast Asian countries.

In 2007, Tang published a study assessing the prevalence of overweight and obesity among adolescents in Ho Chi Minh City showed that the prevalence of overweight and obesity increased from 5.0% and 0.6% in 2002 to 11.7% and 2.0% in 2004, respectively [97]. In addition, another study of pre-school children in Ho Chi Minh City in 2009 found that the prevalence of overweight and obesity was 20.5% and 16.3% respectively [98]. Using a 24-hour diet recall to analyze the dietary habits of primary girls age 7-9 years old showed that girls from urbanized primary school had higher daily intake of animal protein ratio, deficiency in fiber consumption, and high saturated fatty acid consumption. In contrast, girls in the rural settings had a deficiency of energy, fat, animal, protein, and fiber contents [99].

Nguyen's research published in 2011 assessed the nutritional status of children aged 1 to 12 years using the Vietnamese South East Asian Nutrition Survey, a cross-sectional study. This is the most recent and nationally representative sample on prevalence of malnutrition in Vietnam. The study found that under nutrition was more prevalent in rural areas than in urban areas. In contrast, approximately 29% of the urban children were either overweight or obese as compared to 1-6% of children in rural areas of Vietnam [100].

Another study focusing on trends in overweight and obesity in pre-school children in urban areas of Ho Chi Minh City from 2002-2005 found that the prevalence of overweight and obesity almost doubled from 2002-2005 increasing from 21.4% to 36.8%. This increase is more evident in less wealthy districts than in wealthy districts in urban areas [98].

There is even more limited data on risk factors that are associated with childhood obesity in Vietnam. One study that explored these risk factors using a one year follow up survey found that male gender, increased parental overweight, higher paternal education, high birth weight,

longer duration of breast-feeding, and longer duration of sleep hours were significantly associated with overweight/obesity in preschool children in Vietnam [101]. Another study evaluating the dietary intake of preschool children in Vietnam found that dietary intake of the children contained more energy from animal protein and fat and less energy from carbohydrates than the recommended daily average [102]. This shows that there is an imbalance of dietary intake that may be correlated to the nutritional shift of increased consumption of proteins and fat as economic development progresses and availability of food becomes more accessible and diverse. However, there were no studies that looked at the consumption of sugar and sweetened beverages in Vietnam.

Similarly to the findings in more developed countries, higher birth weight and higher parental body mass index was associated with the status of overweight or obese in adolescents age 6-11 years in 2 provinces of Northern Vietnam. In addition, obese children in this study tended to have more visceral fat than subcutaneous fat with associated increase of blood triglyceride level and high rates of hypertriglyceridemia [103].

Most recently published in March 2016, Do and colleagues conducted focus groups with 33 mothers of preschool children age 4-6 years old from urban and rural districts of Ha Noi, Vietnam. The aim of the study was to understand Vietnamese mother's conceptions of childhood overweight and obesity. The study found that mothers are concerned about the impaired social interaction and health problems that are caused by overweight and obesity. In addition, most mothers had limited time to take care of children due to work and lack understanding of factors that may contribute to childhood overweight and obesity. Lastly, mothers expressed that child's grandparents sometimes impede the managing their child's weight [104]. This is notably the first qualitative study that explored Vietnamese's mothers understanding of childhood adiposity and the challenges they face with managing their child's weight.

Future Research Direction

Given what is known about the determinants of childhood overweight and obesity from studies in developed countries, many questions still remain about the determinants of childhood obesity in economic developing countries with increasing rates of childhood obesity such as Vietnam. Collectively, studies on the determinants of childhood obesity in Vietnam have important limitations:

1. Lack of longitudinal follow up
   The few studies done in Vietnam and prevalence data extracted from national surveys are cross-section surveys. The cross-section surveys are limited in that it can only show a snapshot of the prevalence at that time in the child's life and does not follow up with the children during development as adiposity may change with growth and changing environmental factors. There is also limited data on the percentage of children that continue to be overweight and obese in later life.

2. Lack of qualitative data
   There is one qualitative study that examines the mothers and families' understanding of the obesity epidemic. In order to address this epidemic, more data is needed to fill in the gaps of knowledge and support families to help overweight and obese children lead healthier life styles.

3. Lack of nationally represented data from all regions in Vietnam

The studies available have only studied urban communities in South and North Vietnam in very specific cities. These studies miss the nutrition status of children in Central region of Vietnam, less populated cities, and more rural provinces of South and North Vietnam.

Ultimately, the purpose of my research is to address the lack of longitudinal follow up with nationally represented data in Vietnam using the Young Lives dataset to find risk factors associated with childhood overweight and obesity as a child develops. Furthermore, it will also explore the relationship between environmental factors and childhood obesity. Greater understanding of the associated risk factors with longitudinal follow up will target interventions and slow the spread of this epidemic to more rural and poorer provinces in Vietnam.

CHAPTER 2: THESIS

Introduction

There is a large body of evidence that indicates many Asian countries with fast growing economies, like Vietnam, currently face a double burden of malnutrition—underweight and overweight[100]. Arguably, this double burden has been driven by the nutrition transition, which is fueled by economic growth and foreign direct investments. Traditional Vietnamese diet is high in carbohydrates and vegetables while low in animal fat and proteins[2]. This contributes to the population's low in energy intake [3]. However, the diet in Vietnam has changed remarkably. There is an increase of animal sourced foods high in proteins, fats, and oils [4]. This nutrition shift is however not homogenous across all regions of Vietnam as higher body mass index (BMI) is correlated with higher social economic status and living in more urbanized areas[5].

In the last decade, childhood obesity has emerged as a global public health crisis. Though childhood overweight and obesity prevalence is lower in most middle- and low-income economies as compared to high-income economies, the trend of obesity is rising much quicker in developing economies[26]. Most of these data are derived from national surveys looking at obesity rates in adults. There is a lack of up-to-date and nationally representative data on the prevalence and incidence obesity amongst children less than 20 years of age for most low and middle-income countries including Vietnam. Regardless, the rising trends of overweight and obesity in developing economies need to be addressed as it may lead to consequently higher incidence of non-communicable diseases in these countries that are carrying the burden of both underweight and overweight malnutrition.

It is estimated that about 10% of school-aged children worldwide are overweight or obese, which puts them at higher risk for developing chronic diseases[7]. Early childhood obesity is linked to chronic health problems in childhood and significantly increases the risk for chronic health problems in adulthood[8]. In addition to its association with higher BMI in later life, childhood obesity before age 8 is also associated with increased risk of early complications from diabetes and cardiovascular diseases[9]. Some recent studies on childhood overweight and obesity in Vietnam found that overweight and obesity in Ho Chi Minh City rose from 5.8% in 2002 to 13.7% in 2004[105]. In addition, the European inception report, based on World Health Organization's data, Vietnam experienced a 38% increase in the number of obese individuals under the age of 20 from 2010 to 2014[106]. This is higher than most of its Southeast Asia neighbors including Thailand (27% increase), Malaysia (33%), and Indonesia (33% increase)[106]. Compared to its neighboring countries with similar economic growths, Vietnam has lower prevalence but very high percent increase. This provides a unique opportunity to intervene in the progression of the emerging public health crisis of childhood obesity for Vietnam. However, there lacks evidence on risk factors associated with childhood obesity for transitional countries like Vietnam, especially for school-aged children.

The goal of this study is to describe the patterns of nutritional status overweight and obesity in Vietnamese children by using body-mass-index for age z scores as a proxy for nutritional status. The study follows children across three time points: age 1, 5, and 8. In addition to describing the patterns of nutritional status, we examine socio-demographic and modifiable variables at each time point that may be associated with overweight and obesity and its effects on the nutritional patterns in this cohort.

Methods

a. Data Source

Data were analyzed from Vietnamese children in the Young Lives prospective cohort study (http://www.younglives.org.uk/). Three rounds of quantitative surveys of children, households, and communities were collected over a span of 8 years. The surveys were carried out in 2002 (round 1), 2006 (round 2), and 2009 (round 3). The children were enrolled at the age of 1 (round 1) and were followed for each subsequent round of data collection.

The study sites in Vietnam were selected in 2001, using a semi-purposive sampling strategy designed to over sample poor communities. Thirty-one communes were selected with 15 from the poor group (48%), nine from the average group (29%), and seven (23%) from the above average income group. From each sentinel site, 100 children born between January 2001 and May 2002 were selected using simple random sampling. Only one child was selected per household.

b. Anthropometric Variables

For analysis, the outcome was body-mass-index for age z-score. The outcome included the prevalence rates of high BMI for age z-score using the World Health Organization's thresholds for both overweight and obesity. For children under five years old, overweight is defined as BMI>2 z-score and obesity is defined as BMI>3 z-scores. For children 5-19 years of age, the thresholds change to BMI>1 z-score for overweight and BMI>2 z-score for obesity[10].

In round 1 (age 1), the prevalence of overweight was 0.75% and obesity was 0.35%. In round 2 (age 5), the prevalence of overweight was 4.34% and obesity was 4.08%. In round 3 (age 8), the prevalence of overweight was 6.07% and obesity was 4.26%. Since the categories of overweight and obesity in each round are relatively small compared to the overall cohort size, overweight and obese categories were combined for statistical purposes. The final outcome variable is a combined category of "overweight or obese at age 8".

Field workers measured the children's height and weight twice for each round to reduce data collection error. The final recorded height and weight was the average between the two collected data points.

c. Covariates

Covariates were chosen based on causal pathways supported by literature and available data from Young Lives study. Covariates were first analyzed using bivariate regression and advanced only when shown to be statistically significant as indicated by overall p-value of <0.05. Though many variables were strongly associated in bivariate analysis (see Table 2), we adjusted for socio-demographic variables that were most found most significant in literature in our trimmed down model in Table 2.1.

Covariates were divided into child, household, and community characteristics. At the child level, we adjusted for sex. Child age was not adjusted for because the BMI for age Z score has already taken into account age. Male sex was more positively associated with overweight/obesity at age 8.

At the household level, we adjusted for wealth index. Wealth index was calculated as an average of the housing quality index, consumer durables index, and services index. The wealth index value is a measurement of the socioeconomic status of the household. As expected, children from families with a higher wealth index were more likely to be overweight/obese as compared to children from families with a lower wealth index.

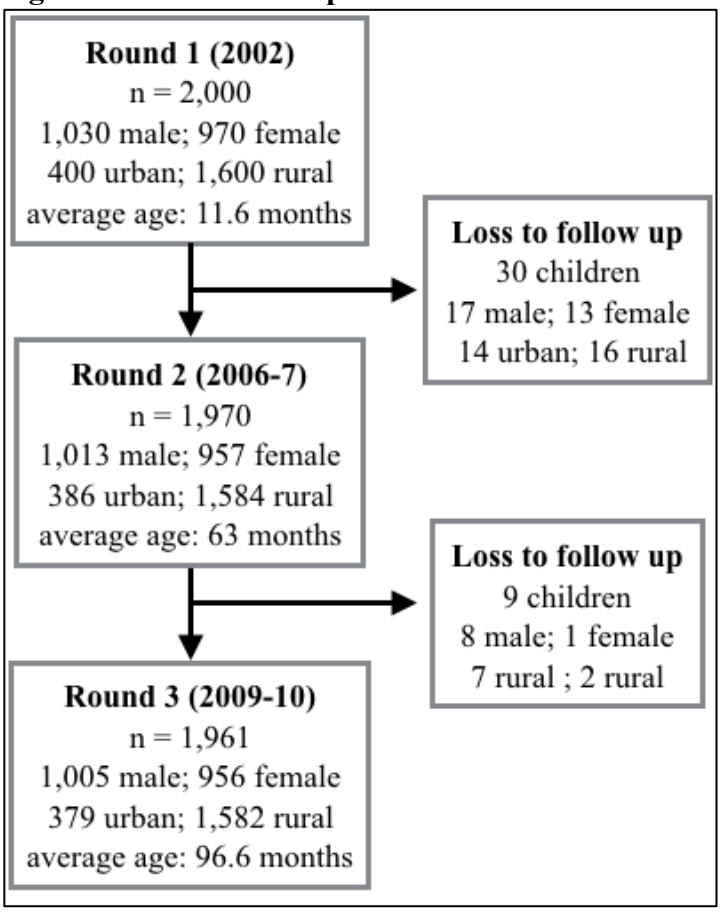
At the community level, we adjusted for site type (urban or rural). Overweight/obesity at age 8 (round 3) was higher for urban communities than rural communities.

Testing for interaction between our covariates, we found that the association for wealth index is different for urban and rural communities. The OR for wealth index in the rural communities is 1.12 as compared to the OR for wealth index in the urban communities of 1.44. This shows that the association between wealth effect and the outcome is greater for the urban community than for rural communities. We kept this interaction term in our models.

d. Sample Size

Of the 2000 children recruited in the first round, 1,961 children remained in round 3. The attrition rate in Young Lives is extremely low. Our final sample size is 1,961 children who remained in round 3 (Figure 3).

Figure 3: Cohort Description



e. Ethics

The ethics committee of Oxford University and research committees in Vietnam reviewed and approved the approach of Young Lives. Parents gave written consent in round 1 and subsequent verbal consent in the later rounds.

Additional the University of California, Berkeley did not require an Institutional Review Board's formal review on the basis that de-identified data was used for analysis.

f. Statistical Analysis

All statistical analyses were conducted in the statistical program STATA 15. We stratified the data by rounds. Details of baseline characteristics can be found in Table 1.

Within each round, the variables were grouped into child characteristics, child nutrition, child physical activity, maternal characteristics, household characteristics, and neighborhood characteristics. The variables selected were based on associations supported by the literature as well as data available from Young Lives surveys. The list of variables tested can be found in Table 2.

To determine if a variable could be included as continuous, linear, or categorical, we first examined the function form by reviewing if variable is linearly related in log odds to the outcome using the LOWESS (Locally Weighted Scatterplot Smoothing) plot function in STATA 15. If the resulting graph shows a linearly relationship, the variable was taken as continuous. If the graph does not show a linear relationship, the variable was divided into categorical data supported by previous literature. Overweight and obesity is a binary outcome.

We completed bivariate analyses using logistic regression to explore the associations of each variable within the subgroups with the child's overweight/obese status at age 8 (round 3). If the variable showed statistical significance (p-value <0.05), we then included it in our adjusted model or parsimonious model in Table 2.1. In the adjusted model, we adjusted for the covariates we've discussed – sex, wealth index, site type, and interaction term between wealth index and site type.

For the variables that were found to be significant in the parsimonious model (Table 3), we added these variables along with other variables that were found to be significant in the adjusted model into extended models to explore the unique contribution that each variable adds to being overweight/obese at age 8. Four models were made adjusting for the same social demographic covariates we did in the parsimonious models (sex, wealth index, site type, and interaction term between wealth index and site type):

- **Model 1:** This model examines concurrent data collected at age 8 (round 3) that were found to be significantly (p-value <0.05) associated with overweight/obesity at age 8 (round 3) in the adjusted model.
- **Model 2:** This model examines early data collected at age 5 (round 2) that that were found to be significantly (p-value <0.05) associated with overweight/obesity at age 8 (round 3) in the adjusted model.
- **Model 3**: This model combines data collected at age 8 (round 3) and age 5 (round 2) that were found to be significantly (p-value <0.05) associated with overweight/obesity at age 8 (round 3) in the adjusted model.
- **Model 4**: This model combines data collected at age 8 (round 3), age 5 (round 2), and very early factors at age 1 (round 1) that were found to be significantly (p-value <0.05) associated with overweight/obesity at age 8 (round 3) in the adjusted model.

Figure 4: Expanded Models

Model	Age 8 Variables	Age 5 Variables	Age 1 Variables
Model 1	✓		
Model 2		✓	
Model 3	✓	✓	
Model 4	✓	✓	✓

✓This checkmark indicate the variables included in those models.

Results

a. Descriptive Results

The characteristics of the study population are described in1. The mean household size is 4.61 people, with 79% of the household located in a rural site type. The wealth index is .49, which means that though the sample has a high percent skewed towards rural sites, we have proportional distribution of socioeconomic status in our sample at baseline. The mother's mean age is 27 and maternal highest level of education is approximately 7th grade. Each mother has on average 2 children.

The mean age for children in round 1 is 12 months, round 2 is 63 months, and round 3 is 97 months. Nearly all the children (98%) were breastfed and most (93%) were breastfed for more than 12 months. The number of boys and girls in the study was roughly equal. The children who were lost to follow-up were randomly spread in the cohort.

The prevalence of childhood overweight/obesity increases with each subsequent round of data collection: age 1 (1.10%), age 5 (8.42%), and age 8 (10.33%). Notably, at age 5, there is a dramatic divergence between the percent increase for overweight and obesity. By age 8, the prevalence for overweight/obesity was two times higher for boys (13%) than girls (7%) (Figure 5).

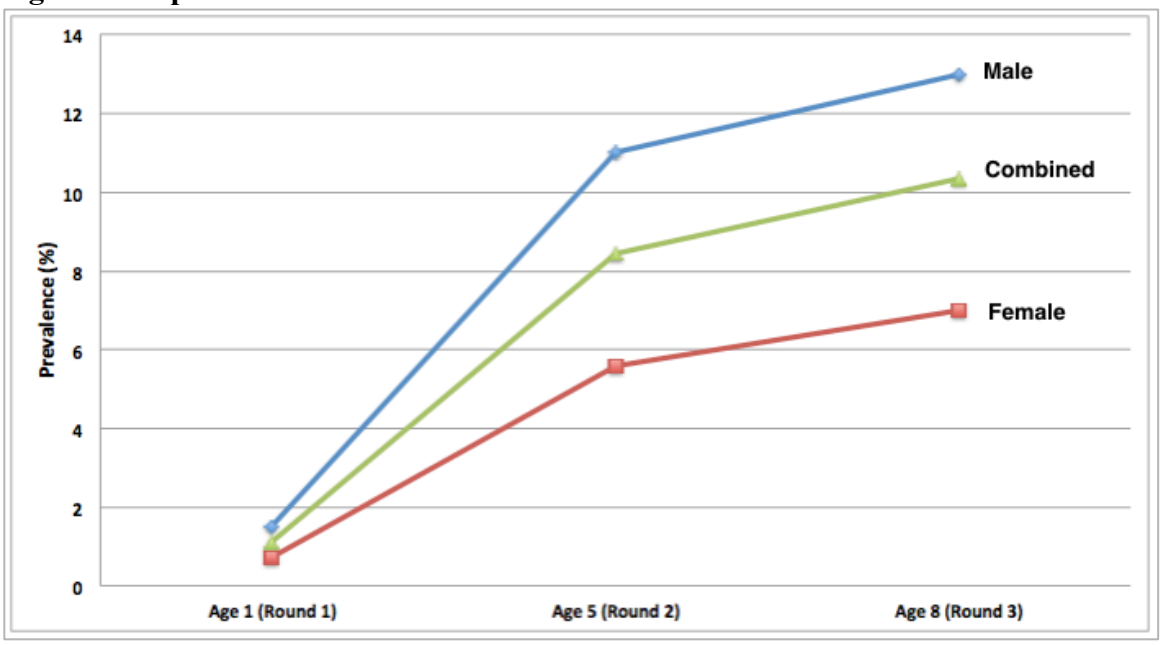
Table 1: Maternal/Child Cohort Characteristics at baseline (Age 1)

Variables		Mean ± SD or N (%) (n=1961)
Household	**Household size**	4.61 ± 1.39
	Wealth index	.49 ± .18
	Site type	
	Urban	400 (20)
	Rural	1,600 (80)
Maternal	**Age of mother**	27.17 ± 5.77
	Highest maternal education (grade)	6.82 ± 3.77
	Number of children born to mother	1.91 ± 1.21
Child	**Sex**	
	Male	1,005 (48.75)
	Female	956 (51.25)

Child age (months)	
Round 1	11.62 ± 3.16
Round 2	63.05 ± 3.75
Round 3	96.56 ± 3.78
Birthweight (grams)	3100.16 ± 446.70
Ever breastfed	1,893 (98.29)
Length of time breastfed (months)	
0-6 months	38 (1.94)
7-12 months	96 (4.89)
12+ months	1,828 (93.17)
Born premature	245 (12.5)
Prevalence of overweight & obesity[1]	
Round 1	22 (1.10)
Round 2	165 (8.42)
Round 3	199 (10.33)

[1]*Overweight and obesity is defined using WHO's definition. Less than 5 years of age, overweight is >2+ SD BMI for age z score; obese >3+SD. Age 5-19, overweight is >1+ SD; obese is >2+ SD.*

Figure 5: Expanded Models



[1]*Overweight and obesity is defined using WHO's definition. Less than 5 years of age, overweight is >2+ SD BMI for age z score; obese >3+SD. Age 5-19, overweight is >1+ SD; obese is >2+ SD.*

b. Bivariate Associations

Pearson's chi-square test was used to check for associations between variables of interest and the outcome at age 1, 5, and 8. Variables including child characteristics, maternal characteristics, household characteristics, neighborhood characteristics, nutrition, and physical activity were found to be associated. If these variables showed significance level of $p<0.05$, they

were then included in the multivariate models. The results from the bivariate associations can be found in Table 2.1 in the appendix.

Table 2: Socio-demographic associations

Variables	Odds Ratio[A] [95% CI]
Sex (Boy)	2.2 [1.6-3.1]***
Site type (Urban)	4.3 [3-6]***
Wealth index (5% increase)	
Urban WI	1.4 [1.3-1.6]***
Rural WI	1.1 [1.1-1.2]***

[A]*The odds ratio for each variable is found after adjusting for the other socio-demographic variables in this table.*
**p<0.05; **p<0.01; ***p<0.001*

c. Socio-economic Associations

Using logistic regression, the socio-demographic variables that we found were significantly associated (p<0.001) with overweight and obesity at age 8 includes male sex (OR=2.2; 95% CI [1.6-3.1]), urban site type (OR=4.3; 95% CI [3-6]), and wealth index (Table 2). Since the wealth index affect urban and rural site types differently, we included the interaction term between wealth index and site type into our adjusted models. For every 5% increase in the wealth index for the urban population, there is nearly a 50% increase in the odds of being overweight (OR=1.4; 95% CI [1.3-1.6]). For every 5% increase for the rural population, the odds of being overweight (OR=1.1; 95% CI [1.1-1.2]) are lower than the urban population, but are still significantly associated with higher wealth index.

d. Parsimonious Model (adjusting for socio-demographic variables)

Adjusting for sex, site type, and wealth index, we examined associations between nutrition and physical activity variables at age 1, 5, and 8 with the outcome. Many variables were explored and were found to be associated, however, only the key findings for the parsimonious models will be discussed below. These key findings are chosen because they are modifiable factors that can be helpful to inform future interventions. The results from these additional variables can be found in Table 2.2 in the appendix.

Nutrition Results

For most nutrition variables, the sample was divided into four equally sized groups (quartiles) based on the consumption of specific nutrition variables in the last 2 weeks. The variables that were divided into quartiles were consumption of powdered milk, eating restaurant/food stalls, milk/milk products, package sweets/snacks, and honey/sugar. The results for the key findings of the adjusted models can be found in Table 3.

Age 1

At age 1, children who breastfed for longer than 6 months (OR=.39; 95% CI [.18-.86]) have about 1/3 the odds of becoming overweight/obese at age 8 compared to children who are breastfed less than 6 months. In other words, longer breastfeeding is protective.

Age 5

At age 5, the variables that were found to be significantly associated with higher odds of overweight/obesity were consumption of honey/sugar, milk/milk products, and powdered milk. Children who were in the highest quartile for honey/sugar consumption had 3 times higher odds of overweight/obesity (OR=2.69; 95% CI [1.76-4.11]) compared to children who were in the lowest quartile of consumption. Children were in the 4th quartile for powdered milk had almost 3 times the odds (OR=2.79; 95% CI [1.62-4.63]) of being overweight/obese compared to children in the lowest quartile. Similarly, children who were in the 4th quartile for milk/milk products consumption had almost 4 times the odds (OR=3.9; 95% CI [1.4-4.04]) compared to children who were in the lowest quartile for milk/milk products consumption.

Nutrition variables from age 5 that were found to be significantly associated with overweight/obesity were frequency of eating in the last 24 hours, consumption of food from restaurant/food stalls, and packaged sweets. For the frequency of eating in the last 24 hours, children who ate 6 times or more at age 5 had about 2 times the odds (OR=2.45; 95% CI [1.29-4.65]) of being overweight/obese compared to children who ate fewer times.

As for eating out at restaurant/food stalls, children who were in the highest quartile at age 5 had about 5 times the odds (OR=4.6; 95% CI [2.58-8.19]) compared to children who were in the lowest quartile.

Age 8

At age 8, milk and honey/sugar consumption was not statistically significantly associated with overweight/obesity. However, children at age 8 who consumed powdered milk above the median had higher odds (OR=1,79; 95% CI [1.08-2.99]) of being overweight/obese compared to children who drank less powdered milk. It was not possible to divide powdered milk at age 8 into quartiles since most children did not consume powdered milk by age 8 so we divided it into two equally sized groups instead.

Additionally, children who ate 6 times or more at age 8 had about 3 times the odds (OR=3.23; 95% CI [1.56-6.78]) of being overweight/obese compared to children who ate fewer times. At age 8, children who were in the highest quartile for eating restaurant/food stalls had about 3 times the odds (OR=2.57; 95% CI [1.54-4.29]) compared to children who were in the lowest quartile.

Physical Activity Results

Children who were driven to school via motorbike by their parents had higher odds of being overweight/obese at both age 5 (OR=3.36; 95% CI [2.10-3.8]) and age 8 (OR=3.8; 95% CI [2.46-5.89]). Additionally, we looked at the number of hours that a child spent playing in the last week for both age 5 and 8, but the variables lost their statistical significance after adjusting for socio-demographic factors. Since we did not have the number of hours children spent watching television, we used the number of televisions owned in a household as a proxy. However, this variable was only significant with higher odds (OR= 4.89; 95% CI [1.39-17.38]) for children who had 2 or more televisions in their homes at age 8 compared to children who had no television.

Table 3: Nutrition & Physical activity variables associations in multivariate adjusted for socio-demographic variables (Parsimonious model)[A]

	Variables	Age 1 OR [95% CI]	Age 5 OR [95% CI]	Age 8 OR [95% CI]
Nutrition Variables	**Length of breastfeeding**			
	(ref is 3 times)			
	7-12 months			
	>12 months	.34 [.12-.96]* .39 [.18-.86]**		
	# of times child ate/day			
	(ref is 3 times)			
	6 + times		2.45 [1.29-4.65]***	3.23 [1.56-6.78]***
	restaurant/food stalls[B]			
	(ref is lowest quartile)			
	2nd quartile		1.2 [.58-2.47]	1.37 [.79-2.36]
	3rd quartile		2.58 [1.42-4.66]***	1.76 [1.08-2.86]**
	4th quartile		4.6 [2.58-8.19]***	2.57 [1.547-4.29]***
	powdered milk[B,C]			
	(ref is lowest quartile)			
	2nd quartile		3.06 [1.77-5.28]***	
	3rd quartile		2.39 [1.39-4.10]***	
	4th quartile		2.79 [1.62-4.63]***	1.79 [1.08-2.99]*
	milk/milk products[B]			
	(ref is lowest quartile)			
	2nd quartile		1.4 [.77-2.57]	.86 [.49-1.52]
	3rd quartile		2.4 [1.4-4.04]***	1.22 [.72-2.05]
	4th quartile		3.9 [1.4-4.04]***	1.06 [.63-1.80]
	packaged sweets/ snacks[B]			
	(ref is lowest quartile)			
	2nd quartile		1.36 [.81-2.30]	2.08 [1.36-3.18]***
	3rd quartile		2.04 [1.32-3.16]***	2.44 [1.59-3.76]***
	4th quartile		2.69 [1.76-4.11]***	3.47 [2.38-5.07]***
	Honey/sugar[B]			
	(ref is lowest quartile)			
	2nd quartile		1.51 [.97-2.30]	.94 [.63-1.42]
	3rd quartile		2.04 [1.32-3.16]***	.98 [.49-1.98]
	4th quartile		2.69 [1.76-4.11]***	1.53 [2.38-5.07]
Physical Activity Variables	**Mode of transportation**			
	(ref is walking)			
	motorbike		3.36 [2.10-5.05]***	3.8 [2.46-5.89]***
	Hours child spent playing in last week			
	(ref is <6 hours)			
	6-10 hours		1.62 [.98-2.66]	1.0 [.62-1.29]
	10+ hours		1.21 [.69-2.13]	.55 [.46-1.14]

Number of TVs owned in household *(ref is 0)*		
1 TV	1.98 [.92-4.22]	2.42 [.73-8.03]
2+ TV	2.81 [1.12-7.01]	4.89 [1.39-17.38]*

[A]All variables are adjusted for sex, site type, wealth index, and interaction term of wealth and site type.
[B]The sample was divided into four equally sized groups or quartiles based on consumption within the last 2 weeks.
[C]The sample for powdered milk at age 8 was divided into two equally sized groups above and below the median since it was not possible to divide it into quartiles.
**p<0.05; **p<0.01; ***p<0.001*

e. Extended Models

In our extended models (Figure 4), we controlled for multiple factors in addition to socio-demographic variables to find the unique contribution of each factor that was found to be significant in our adjusted parsimonious model. One limitation of these extended models is that since they are adjusting for multiple variables at a time, correlations between these variables may be a factor in reducing the significance of the variables. Multiple iterations were made of each model and the model that we estimated to have the least correlations based on literature was chosen. The additional models can be found in Table 4.1 in the appendix.

In model 1, we adjusted for socio-demographic, nutrition, and physical activity variables at age 8 to observe the unique contributions of concurrent risk factors. In model 2, we adjusted for the same groups of variables at age 5 to examine the unique contributions of early risk factors. Model 3 combines both concurrent and early factors to examine their unique contributions to overweight/obesity at age 8. Lastly, model 4 combines all factors including concurrent factors (age 8), early factors (age 5), and very early factors (age 1).

Socio-demographics Variables

The only socio-demographic variable that consistently showed statistical significance across all four models is male sex. Males have 3 to 4 times the odds of being overweight/obese compared to girls. Higher wealth index showed higher odds only in model 2 and model 3. In model 1, we included sibling's body mass index for age Z score and found that children with siblings who were underweight had lower odds of being overweight/obese. However, children who had siblings with higher body mass index for age z-score did not have statistical significance in predicting the child's overweight/obese status so we did not keep it in the model. As for maternal characteristics, children with mothers whose highest education levels were high school or higher had higher odds of being overweight/obese in model 5 (OR=2.08; 95% CI [1.14-3.77]).

Nutrition Variables

The numbers of times children ate in the last 24 hours was only significant in model 2. Children who ate 6 times or more had higher odds (OR=2.93; 95% CI [1.04-8.27]) compared to children who had eaten fewer times. Children who were in the highest quartile for packaged sweets in the last two weeks had higher odds in both model 3 (OR=2.09; 95% CI [1.16-3.78]) and model 4 (OR=2.15; 95% CI [1.38-3.37]). As for consumption of powdered milk, children who were in the highest quartile had higher odds only in model 4 (OR=1.73; 95% CI [1.1-3.0]) compared to those who were in the lowest quartile. Powdered milk consumption lost its statistical significance in

other models. Likewise, consumption of food from restaurants/food stalls, honey/sugar, and length of breastfeeding were no longer statistically significance in the extended multivariate models.

Physical Activities Variables

Children who are driven to school via motorbike by their parents were consistently found to have higher odds of being overweight/obese in both model 2 (OR=1.63; 95% CI [1.36-5.10]) and model 3 (OR=2.85; 95% CI [1.41-5.79]).

Table 4: Extended multivariate models

Variables	**Model 1 (Age 8) Concurrent factors** OR [95% CI]; n=380	**Model 2 (Age 5) Early factors** OR [95% CI]; n=421	**Model 3 (Age 5 & 8) Concurrent & Early factors** OR [95% CI]; n=420	**Model 4 (Age1, 5, & 8) Combined factors** OR [95% CI]; n=1,004
Social demographics				
wealth index	1.02 [.83-1.26]	1.18 [1.04-1.35]*	1.23 [1.01-1.51]*	1.05 [.96-1.15]
sex (boy)	3.79 [1.48-9.70]***	3.5 [1.98-6.17]***	3.21 [1.76-5.88]***	2.58 [1.63-4.08]***
site type (urban)	.05 [.00-3.99]	1.18 [.12-10.92]	.43 [.03-6.38]	1.15 [.18-7.39]
interaction term (wealth index x site type)	1.42 [1-1.99]*	1.05 [.88-1.24]	1.13 [.93-1.40]	1.09 [.95-1.25]
Round 3				
transport (motorbike 1)[C]	5.21 [1.92-14.2]***			
sibling BMI[A] (underweight)	.20 [.08-.48]***			
times eaten (6+ times)	1.09 [.42-2.85]			
packaged sweets[B]	1.13 [.47-2.7]		.7 [.37-1.32]	
restaurant/stalls[B]	1.12 [.36-3.47]		1.6 [.66-3.89]	1.30 [.75-2.26]
Round 2				
transport (motorbike)[C]		1.63 [1.36-5.10]**	2.85 [1.41-5.79]**	
times eaten (6+ times)		2.93 [1.04-8.27]*	1.56 [.625-3.93]	
packaged sweets[B]			2.09 [1.16-3.78]*	2.15 [1.38-3.37]***
powdered milk[B]		1.27 [.68-2.35]	1.41 [.73-2.75]	1.73 [1.1-3.0]*
restaurant/stalls[B]		1.27 [.67-3.37]		

honey/sugar[B]	1.12 [.67-2.38]	1.42 [.89-2.28]
Round 1		
length breastfed (>12 months)[D]		.88 [.44-1.75]
mom education (high school +)[E]		2.08 [1.14-3.77]*

[A]Sibling's BMI was not included in Table 3, but it was found to be significantly associated with overweight/obesity at age 8 so it was included in this model (See appendix – Table 2.2)
[B]Nutrition variables are comparing the highest quartile consumption groups with the lowest quartile group.
[C]Mode of transportation via motorbike to school is compared to children who walk to school.
[D]Length of breastfeeding is greater than 12 months compared to those who breastfed for 12 months or less.
[E]Mother's education is comparing mothers with grade 10 or higher to those with less years of education.
**p<0.05; **p<0.01; ***p<0.001*

Discussion

Childhood overweight and obesity is prevalent in the Young Lives Cohort and increases with age. The prevalence was almost double for boys than girls at every age. At age 8, the prevalence for overweight/obese was 10.33% using the World Health Organization's standards. The combined prevalence of overweight and obesity at age 8 is higher than the 5.6% prevalence from the national Vietnamese nutrition survey in 2010[107]. This is consistent with the findings from the Ng et al 2015 review that Vietnam has one of the highest increases in percentage of obesity from 2010-2014[106]. While Vietnam is still facing a high but decreasing burden of childhood malnutrition, we are beginning to see an emerging issue of childhood overweight/obesity[107].

The socio-demographic findings of this study are consistent with cross-sectional studies done in Vietnam. Boys from urban areas living in homes with higher wealth index have higher odds of being overweight/obese. Boys may have higher odds due to historical gender preferences for boys leading families to spend more resources and money on boys. Another hypothesis for finding higher odds for boys is the misconception in the differences of nutritional needs for boys versus girls[104]. Families may think boys need higher energy intake than girls due to conceptions of growth trajectories. As for the higher odds of overweight/obesity for urban areas compared to rural areas, the availability and density of processed foods and sugary drinks may be higher in urban areas than rural areas. Additionally, urban areas in Vietnam are very high density areas with crowded traffic conditions leading to less space for children to walk to school and/or play. The wealth index also affected urban and rural areas differently. In urban areas, higher wealth index was associated with higher odds of overweight/obesity than rural areas. This again could be due to having more economic power combined with the higher availability and accessibility of sugary milk, packaged snacks, and sugary drinks. Overall, boys with higher wealth index living in urban areas have the highest odds of overweight/obesity. This is helpful in considering target populations for future studies and intervention programs to maximize impact of reducing overweight/obesity.

The causes of childhood overweight/obesity are multifactorial as described by Davison and Birch's ecological model[60]. However, due to availability of variables in Young Lives study, our study focused mostly on modifiable factors in nutrition and physical activity variables that are associated with childhood overweight/obesity at age 8. The nutrition and physical activity variables were separated into very early factors (age 1), early factors (age 5), and concurrent factors (age 8).

We explored both parsimonious models that only adjusted for socio-demographic factors and extended models that adjusted for various factors including concurrent factors, early factors, and very early factors. The extended models' main limitation is that multicollinearity may have reduced the statistical significance for variables included in the adjusted models that were found to be significant prior. Furthermore, adjusting for multiple factors in each model produced smaller cell size for combinations of exploratory variables decreasing the precision.

Yet we chose to investigate the extended models to explore the unique contribution of each factor while adjusting for all other associated factors. In our extended models, male sex was consistently associated with higher odds in every model, providing us with more evidence of this finding from our socio-demographic findings. We also found other factors that were consistent with our parsimonious findings. The factors that were associated with higher odds in the various extended models included mode of transportation to school, consumption of packaged sweets, consumption of powdered milk, and numbers of times eaten. Two unique findings that we found in our extended model were the associations with sibling's body mass index for age Z score and maternal education. Children with siblings who were underweight had lower odds adjusted for all else at age 8. This finding suggests that households with children who were underweight were more likely to be underweight themselves. In regards to maternal education, children with mothers with higher education had higher odds of overweight/obesity, possibly because these mothers may be working outside the home and thus leaving the child's caretaker or child with more money to buy snacks or sugary drinks.

Though the findings in our extended models were helpful to understand the unique contributions of the various risk factors, the findings from the parsimonious models may be more helpful in determining the direction of future research and intervention programs to help prevent and reduce the overweight/obesity in Vietnam.

The key findings in our parsimonious model (Figure 6) suggest that nutritional factors and physical activity factors affect the odds of being overweight/obese at age 8. The findings from nutrition factors show that length of breastfeeding is associated with lower odds of overweight/obesity at age 8. This finding is the only protective nutrition factor we found in our study that is consistent with previous literature from many other countries[78,108,109]. A possible pathway proposed for this protective effect may be that longer breastfeeding may preclude inappropriate complementary feeding practices that could lead to excessive weight gain in early childhood[110].

The early risk factors at age 5 that we found were associated with overweight/obesity are increased in frequency of eating, eating food from restaurants/food stalls, powdered milk, milk/milk products, packaged sweets/snacks, and honey/sugar. Eating six or more times a day showed higher odds because children may be snacking more often leading to excessive weight gain[32]. While the children are snacking more, they may also be eating more packaged sweets, foods containing sugar and honey, and at restaurant/food stalls. The USDA Foreign Agriculture Service Report for Vietnam's retail foods in 2013 reported that there is an increase in a growing number of western-minded consumers and increasing consumer acceptance of processed and packaged products. Additionally, Vietnam is now the 13th largest export market for food and beverages from the United States[111].

Similarly, milk consumption has dramatically increased. Forbes in 2016 highlighted the massive success of Vinamilk, Vietnam's largest dairy company, in its remarkable growth in sales within the last few decades. Vinamilk is one of many dairy companies in Vietnam that produce milk from skim-milk powder, water, oils, sugar, and other additives[112]. While milk and powdered

milk do have some nutritional benefits, the excess intake of sugar and additives may be a significant contributor to excess weight gain. There is substantial evidence in literature that consumption of sugar sweetened beverages, particularly carbonated soft drinks, may be the main contributor to the epidemic of overweight and obesity due to the high sugar content[113,73]. However, there has been no reference in literature to sugary milk consumption. This is the first study to look at the association between sugary milk consumption and child overweight and obesity.

Overall economic growth is a major driver for Vietnam's increased in availability and accessibility of packaged snacks, junk foods, fast foods (i.e., restaurants/stalls, food chains, etc), and sugary milk (i.e., powdered milk and milk/milk products). Furthermore, Vietnam's sizable young population, rising middle-class incomes, and female labor force participation may be driving Vietnamese consumerism, especially the preference for modern market retailers and fast food chains[111]. Unfortunately, children are often the targets for the marketing of unhealthy foods, packaged snacks, and sugary drinks. These foods are often masked as being healthy for children's growth and development. These nutritional factors also were also associated with higher odds of overweight/obesity at age 8.

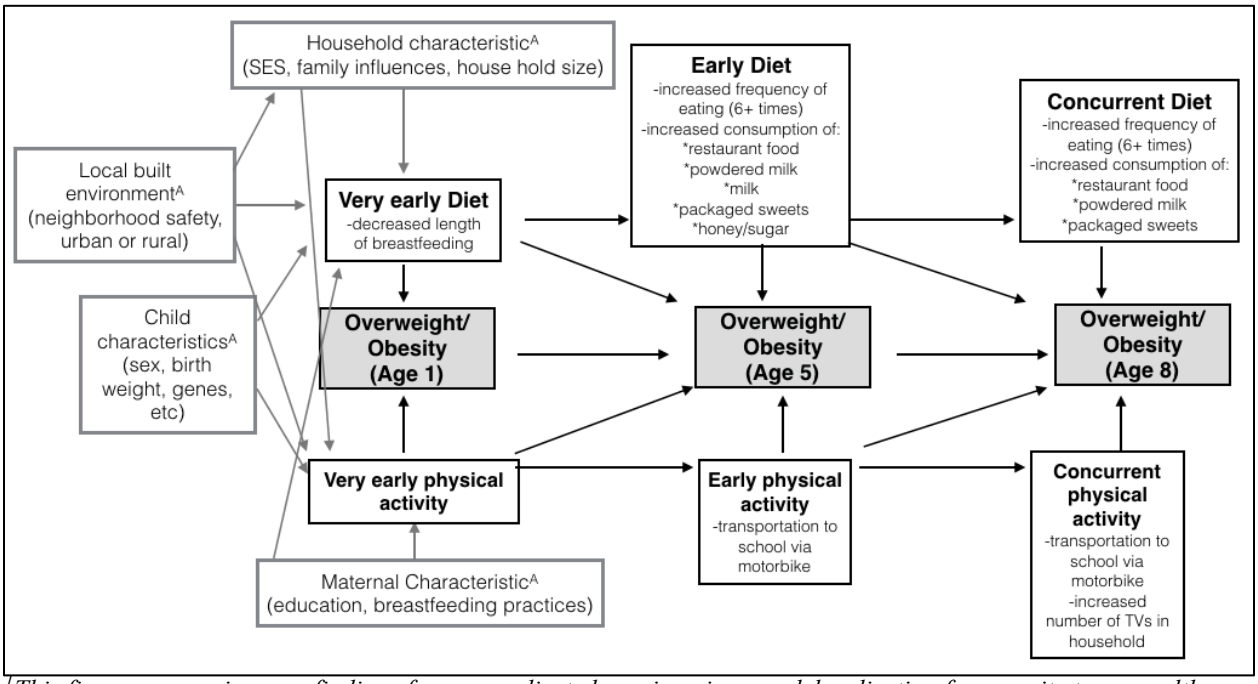
At age 5, various variables were investigated to understand the physical activity levels of children in this cohort using the parsimonious model. However, we were limited in the availability of variables. The only variable that was found to be statistically significant and increasing odds is mode of transportation to school via motorbike compared to walking to school. This variable is a proxy for physical activity since children who walk to school would be assumed to have higher physical activity levels than children who get driven to school. Furthermore, with worsening traffic conditions in Vietnam, children living in neighborhoods that are not as safe for walking to school may have even more reduced physical activity in their home environment due to limited safe space to play[114]. At age 8, we found that having more televisions in the household is associated with higher odds of overweight/obesity. Though it's not accurately measuring the number of hours children are watching television, we used this as a proxy for the number of hours children may spend watching television. Children who have more televisions in their household have more access to watching television and thus reduced physical activity levels. The numbers of hours spent in various activities including watching television or playing outside in addition to neighborhood safety and accessibility of safe spaces to play should be investigated.

Though we looked at both concurrent factors and early factors, since overweight and obesity develops over time, interventions addressing both nutritional and physical activity factors should begin before age 8. Starting these interventions at an earlier age would be more impactful in reducing the chronicity of this health crisis.

The strength of this study is that we utilized a large longitudinal cohort dataset with very low attrition (1.5%). The study was able to explore associations between urban and rural locations in addition to investigating risk factors at three time points (age 1, 5, and 8), which has not been done before.

The limitations of this study include limited generalizability to the whole country of Vietnam because of pro-rural sampling that Young Lives Cohort study utilized. Weights were not provided to correct for this, therefore applying our findings nationally is not possible. This study was also limited by the availability of variables that we were able to explore due to the nature of secondary data analysis. Lastly, odds ratio findings are associations and not causations.

Figure 6: Summary of findings from parsimonious adjusted models[1]



[1]*This figure summarizes our findings from our adjusted parsimonious models adjusting for sex, site type, wealth index, and interaction term between wealth index and site type.*
[A]*The domains in the gray boxes continue to affect childhood overweight and obesity in the same direction in the subsequent rounds (age 5 and 8).*

Conclusions

In Vietnam, there is a substantial percent of overweight/obesity in school-aged children and the percent increased with age from 2002-2010. Boys from families with higher socio-economic status living in urban areas have the highest odds of being overweight/obese. This finding suggests children in Vietnam are also at higher risk for non-communicable diseases. Even though the increase in obesity percentage is high, the prevalence of overweight/obesity is comparatively lower than levels in higher income countries. There is an urgent need to explore risk factors that contribute to this rising rate of overweight/obesity. This study showed that length of breastfeeding is protective, while multiple nutrition and physical activity factors were associated with higher odds of overweight/obesity at age 5 and 8. The summary of our findings can be found in Figure 3. These findings can help inform future research and targeted nutritional policies and intervention programs to prevent and reduce rates of childhood obesity in Vietnam.

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Appendix

Table 2.1 - Bivariate associations with overweight and obesity at Round 3 (age 8)

	Variable	OR[CI]	P-value compared to reference	Overall P-value[1]
ROUND 3 (Age 8)				
Child Characteristic	**Sex (boy)**	2.005 [1.472 2.730]	<0.001	<0.001
	Sleep (hours)			
	10 hours (reference)			0.006
	<10 hours	.614 [.446 .846]	0.003	
	>10 hours	.627 [.398 .985]	0.043	
Household Characteristics	**Site type (urban)**	6.648 [4.884 9.042]	<0.001	<0.001
	Sibling's BMI			
	Normal BMI			<0.001
	Less than normal BMI	.189 [.119 .298]	<0.001	
	Overweight/obese	1.881 [.673 5.2539]	0.228	
Neighborhood Characteristics	**Neighborhood is safe to walk to School**			
	Child Agrees (reference)			0.1427
	Child is Ambivalent	.761 [.488 1.185]	0.227	
	Child Disagrees	1.048 [.686 1.602]	0.827	
	The neighborhood is safe for children	1.033 [0.14 0.891]	0.891	
	Mother feels safe letting child go into street on his/her own			
	Child agrees (reference)			<0.001
	Ambivalent	2.536 [1.523 4.223]	<0.001	
	Disagrees	2.536 [1.692 3.801]	<0.001	
Nutrition	**Estimated <u>quantity</u> of soft drinks bought & consumed in last 2 weeks**			
	0 times (reference)			0.004
	<5 times	1.291 [.793 2.102]	0.304	
	>5 times	2.138 [1.362 3.357]	0.001	
	Estimated <u>quantity</u> of packaged sweets bought & consumed in last 2 weeks			
	0 (reference)			<0.001
	1-2 times	2.124 [1.393 3.237]	<0.001	
	3-5 times	1.730 [1.393 3.237]	0.003	
	>5 times	1.694 [1.055 2.719]	0.029	
	Estimated <u>quantity</u> of powdered milk/formula			
	0 (reference)			<0.001
	1 more times	3.160 [1.784 4.270]	<0.001	
	Estimated <u>quantity</u> of milk/milk products bought & consumed in last 2 weeks			
	0 times (reference)			<0.001
	1-5 times	2.157 [1.251 3.720]	0.006	

5-15 times	2.748 [1.785 4.230]	<0.001	
>15 times	3.866 [2.505 5.966]	<0.001	
Estimated quantity of prepared foods bought & consumed in last 2 weeks			
0 times (reference)			<0.001
1-5 times	.998 [.510 1.953]	0.996	
5-10 times	3.677 [2.179 6.208]	<0.001	
10-15 times	4.214 [2.685 6.615]	<0.001	
>15 times	7.550 [4.769 11.951]	<0.001	
Estimated VND value bought and consumed for soft drinks in last 2 weeks			
Lowest quartile			<0.001
2nd quartile	1.502 [.878 2.572]	0.138	
3rd quartile	2.510 [1.456 4.324]	0.001	
Highest quartile	2.084 [1.184 3.667]	0.011	
Estimated VND value bought and consumed for sugar/honey in last 2 weeks			
Lowest quartile			0.504
2nd quartile	.781 [1.298 3.303]	0.187	
3rd quartile	.813 [2.54 6.071]	0.517	
Highest quartile	.776 [2.537 6.071]	0.219	
Estimated VND value bought and consumed for packaged sweets in last 2 weeks			
Lowest quartile			<0.001
2nd quartile	2.078 [1.360 3.175]	0.001	
3rd quartile	2.443 [1.587 3.761]	<0.001	
Highest quartile	3.471 [2.375 5.0714]	<0.001	
Estimated VND value bought and consumed for prepared food in last 2 weeks			
Lowest quartile			<0.001
2nd quartile	1.652 [.983 2.777]	0.058	
3rd quartile	3.084 [2.003 4.749]	<0.001	
Highest quartile	8.764 [5.983 12.840]	<0.001	
Estimated VND value bought and spent for index child in presents and treats			
None (reference)			0.026
Lowest spending group	2.734 [.942 7.933]	0.064	
Middle spending group	2.588 [.924 7.252]	0.070	
Highest spending group	4.217 [1.520 11.698]	0.006	
Did child eat sweet, honey, or sugary drinks in the last 24 hours?	1.805 [1.262 2.5827]	0.001	0.001
Number of times child ate in the last 24 hours			
3 times (reference)			<0.001

	4-5 times	2.509 [1.368 4.601]	0.003	
	6-7 times	7.846 [4.152 14.825]	<0.001	
Physical Activities	**Hours child spent playing/general leisure time in the last week (during the week)**			
	4-5 hours (reference)			0.008
	<4 hours	1.024 [.737 1.423]	0.889	
	>5 hours	.545 [.361 .822]	0.004	
	Hours child spent in extra class outside of school			
	0 (reference)			<0.001
	1-2 hours	1.656 [1.188 2.309]	0.003	
	3+ hours	.786 [.530 1.167]	0.232	
	Transportation to School			
	Walking (reference)			<0.001
	Bike	1.322 [.813 2.152]	0.261	
	Motorbike	7.398 [5.022 10.899]	<0.001	
	Hours child spent studying at home			
	0 (reference)			0.454
	1 hour	1.716 [.730 4.03]	0.216	
	2 hours	1.642 [.692 3.874]	0.257	
	3+ hours	2.175 [.830 5.705]	0.114	
	Child spent time in extra class outside of school in the last 6 months	1.057 [.775 1.442]	0.726	0.726
ROUND 2 (Age 5)				
Child Characteristics	**Hours spent sleeping**			
	10 hours (reference)			0.225
	Less than 10 hours	1.352 [.942 1.942]	0.101	
	More than 10 hours	1.041 [.702 1.543]	0.841	
Mother's Characteristics	**Mother's education**			
	No education (reference)			<0.001
	Primary school (grade 1-5)	4.684 [1.420 15.451]	0.011	
	Middle school (grade 6-9)	5.582 [1.738 17.926]	0.004	
	High school (10-12)	17.018 [5.174 55.981]	<0.001	
	University or Vocation school	43.463 [13.213 142.974]	<0.001	
	Mother's BMI			
	Normal BMI: 18.5 to 23 (reference)			<0.001
	Underweight: <18.50	.201 [.088 .462]	<0.001	
	Overweight: >23	2.374 [1.726 3.265]	<0.001	
	Mother's perception of child's weight for overweight and obese children			
	Mother misidentifies child as normal or lighter than average	2.756 [1.372 5.533]	0.004	0.004
Household	**Wealth index**	1.310 [1.241 1.383]	<0.001	

Characteristics	**Owns a Television**	5.443 [2.761 10.730]	<0.001	<0.001
	Number of Television in household			
	0 (reference)			<0.001
	1 TV	4.333 [2.187 8.586]	<0.001	
	2+ TV	22.747 [10.734 48.203]	<0.001	
Nutrition	**Food diversity: sum of different types of food groups eaten in the last 24 hours (0-14)**	1.551 [1.423 1.686]	<0.001	<0.001
	Food diversity index			
	Low (≤3 food groups) reference			<0.001
	Medium (4-5 food groups)	1.721 [.390 7.590]	0.473	
	High (≥6 food groups)	6.053 [1.476 24.824]	0.012	
	Number of times child ate within the last 24 hours			
	3 times (reference)			<0.001
	<3 times	2.453 [.295 20.428]	0.407	
	4-5 times	1.887 [1.069 3.332]	0.029	
	6+ times	6.747 [3.863 11.784]	<0.001	
	Estimated VND of powdered/formula milk bought & consumed in last 2 weeks			
	Lowest quartile			<0.001
	2nd quartile	3.511 [2.134 5.775]	<0.001	
	3rd quartile	5.179 [3.261 8.225]	<0.001	
	Highest quartile	9.246 [6.027 14.187]	<0.001	
	Estimated VND of packaged sweets bought and consumed in the last 2 weeks			
	Lowest quartile			<0.001
	2nd quartile	1.315 [.812 2.130]	<0.001	
	3rd quartile	2.395 [1.615 3.552]	<0.001	
	Highest quartile	3.427[2.350 4.987]	<0.001	
	Estimated VND of sugar/honey bought and consumed in the last 2 weeks			
	Lowest quartile			<0.001
	2nd quartile	2.386 [1.599 3.560]	<0.001	
	3rd quartile	2.560 [1.711 3.830]	<0.001	
	Highest quartile	1.788 [1.141 2.801]	0.011	
	Estimated VND of milk/milk products bought and consumed in the last 2 weeks			
	Lowest quartile (reference)			<0.001
	2nd quartile	1.408 [.771 2.570]	0.265	
	3rd quartile	2.410 [1.437 4.040]	0.001	

	Highest quartile	3.901 [1.437 4.041]	<0.001	
	Estimated VND of prepared foods (restaurant/food stalls) bought and consumed in the last 2 weeks			<0.001
	Lowest quartile (reference)			
	2nd quartile	1.204 [.585 2.475]	0.615	
	3rd quartile	2.579 [1.427 4.661]	0.002	
	Highest quartile	4.606 [2.590 8.194]	<0.001	
	How much money spent on treats or present was spent on index child?			
	None of it (reference)			0.215
	Less than half	3.25 [.688 15.357]	0.137	
	About half	3.962 [.891 17.609]	0.070	
	More than half	7.583 [1.366 42.091]	0.021	
	All	3.578 [.815 15.701]	0.091	
	What is the money in VND of the total amount purchased in last 12 months for treats or present was spent on index child?			
	Lowest quartile			<0.001
	2nd quartile	2.505 [1.419 4.423]	0.002	
	3rd quartile	3.904 [2.310 6.599]	<0.001	
	Highest quartile	6.321 [2.310 6.599]	<0.001	
Physical Activity	**Transportation to School**			<0.001
	Walking (reference)			
	Bike	1.173 [.730 1.886]	0.509	
	Motorbike	6.317 [4.291 9.300]	<0.001	
	Hours child spent playing/general leisure time in the last week (during the week)			
	<6 hours (reference)			<0.001
	6-10 hours	.527 [.352 .789]	0.002	
	>10 hours	.375 [.240 .586]	<0.001	
	Hours child spent studying outside of school or extra classes in the last week (during the week)			
	0 hour (reference)			0.002
	1 hour	1.810 [1.003 2.518]	0.001	
	2+ hours	1.590 [1.003 2.518]	0.048	
	Hours time spent in school during the week			
	5-7 hours (reference)			<0.001
	<5 hours	1.139 [.688 1.888]	0.613	
	>7 hours	3.222 [1.984 5.232]	<0.001	
ROUND 1 (Age 1)				
Child Characteristics	**Birth weight (grams)**			
	<=2600 grams (reference)			<0.001
	>2600 to <3600	3.074 [1.881 5.024]	<0.001	

	grams			
	>=3600 grams	4.918 [2.762 8.757]	<0.001	
	Child born premature	1.946 [1.334 2.839]	<0.001	<0.001
	Age order of child			
	No siblings (reference)			0.009
	Youngest child	.631 [.469 .848]	0.002	
	Middle or oldest child	1.382 [.160 11.938]	0.769	
	Perception of size at birth			
	Average (reference)			0.008
	Smaller	1.060 [.718 1.564]	0.770	
	Larger	1.785 [1.232 2.587]	0.002	
Mother's Characteristics	**Mother's age (years)**			
	>=24 to <=28 (reference)			<0.001
	<24	.288 [.181 .459]	<0.001	
	>28	1.052 [.764 1.450]	0.754	
	Mother's happiness	1.326 [.948 1.854]	0.099	0.099
Household Characteristics	**Number of adults in household**			
	2-3 (reference)			0.008
	3 or more	1.488	0.008	
	Number of children born to mother			
	1 (reference)			0.004
	2 children	.825 [.600 1.133]	0.234	
	3 children	.469 [.268 .822]	0.008	
	4 children	.314 [.135 .729]	0.007	
	Number of boys born to mother			
	0 (reference)			0.042
	1 boy	1.473 [1.048 2.070]	0.026	
	2 boys	1.293 [.813 2.057]	0.277	
	3 boys	.442 [.135 1.450]	0.178	
	Number of girls born to mother			
	0 (reference)			<0.001
	1 girl	.540 [.391 .745]		
	2 girls	.441 [.266 .729]		
	3 girls	.391 [.192 .794]		
	Child has siblings	.673 [.501 .903]	0.008	0.008
	Sibling composition in family			
	Only child (reference)			0.002
	Only girl with male siblings	.250 [.114 .544]	<0.001	
	Only male with female siblings	.885 [.570 1.374]	0.586	
	All female family	.641 [.389 1.056]	0.081	
	All male family	.923 [.577 1.476]	0.737	
	Male & female mix family	.415 [.206 .837]	0.014	
	Number of adults in household caring for child			

	1-2 members (reference)			0.129
	3 members	1.453 [1.012 2.085]	0.043	
	4+ members	1.139 [.798 1.626]	0.473	
Nutrition	**Length of breast feeding (m)**			
	0-6 months (reference)			<0.001
	7-12 months	.197 [.081 .479]	<0.001	
	>12 months	.138 [.071 .270]	<0.001	

[1] *Overall P-value = Pearson's chi-square test*

Table 2.2 - Analysis adjusting for sex, site type (urban or rural), wealth index, and interaction term (wealth index & site type)

	Variable	OR[CI]	P-value compared to reference	Overall P-value[1]
ROUND 3 (Age 8)				
Child Characteristic	**Sex (boy)**	2.209 [1.050 1.201]	<0.001	<0.001
	Sleep (hours)			
	10 hours (reference)			0.135
	<10 hours	.7162 [.503 1.020]	0.064	
	>10 hours	.721 [.441 1.180]	0.193	
Household Characteristics	**Site type (urban)**	4.284 [3.038 6.040]	<0.001	<0.001
	Sibling's BMI			
	Normal BMI			<0.001
	Less than normal BMI	.318 [.191 .529]	<0.001	
	Overweight/obese	2.810 [.798 9.904]	0.108	
Neighborhood Characteristics	**Neighborhood is safe to walk to School**			
	Child Agrees (reference)			0.900
	Child is Ambivalent	.895 [.546 1.466]	0.659	
	Child Disagrees	.905[.561 1.458]	0.681	
	The neighborhood is safe for children	1.210 [.726 2.0164]	0.464	0.464
	Mother feels safe letting child go into street on his/her own			
	Child agrees (reference)			0.025
	Ambivalent	1.949 [1.124 3.378]	0.017	
	Disagrees	1.732 [1.123 2.670]	0.013	
Nutrition	**Estimated quantity of soft drinks bought & consumed in last 2 weeks**			
	0 times (reference)			0.092
	<5 times	.686 [.396 1.189]	0.179	
	>5 times	1.469 [.883 2.443]	0.138	
	Estimated quantity of packaged sweets bought & consumed in last 2 weeks			
	0 (reference)			0.064
	1-2 times	1.395 [.868 2.242]	0.169	
	3-5 times	1.300 [.875 1.930]	0.193	

>5 times	1.990 [1.175 3.369]	0.010	
Estimated quantity of powdered milk/formula			
0 (reference)			0.002
1 more times	1.912 [1.278 2.862]	0.002	
Estimated quantity of milk/milk products bought & consumed in last 2 weeks			
0 times (reference)			0.166
1-5 times	1.625 [.906 2.917]	0.103	
5-15 times	1.691 [1.045 2.736]	0.032	
>15 times	1.407 [.833 2.375]	0.201	
Estimated quantity of prepared foods bought & consumed in last 2 weeks			
0 times (reference)			<0.001
1-5 times	.748 [.510 1.953]	0.421	
5-10 times	2.397 [2.179 6.208]	0.003	
10-15 times	1.992 [2.685 6.615]	0.013	
>15 times	2.659 [4.769 11.951]	0.001	
Estimated VND value bought and consumed for soft drinks in last 2 weeks			
Lowest quartile			0.092
2nd quartile	.686 [.396 1.189]	0.179	
3rd quartile	1.469 [.884 2.443]	0.138	
Highest quartile	1.371 [.795 2.363]	0.193	
Estimated VND value bought and consumed for sugar/honey in last 2 weeks			
Lowest quartile			0.504
2nd quartile	.781 [1.2967 3.303]	0.187	
3rd quartile	.813 [2.537 6.071]	0.517	
Highest quartile	.776 [2.537 6.071]	0.219	
Estimated VND value bought and consumed for packaged sweets in last 2 weeks			
Lowest quartile			<0.001
2nd quartile	2.078 [1.360 3.175	0.001	
3rd quartile	2.443 [1.587 3.761]	<0.001	
Highest quartile	3.471 [2.375 5.0714]	<0.001	
Estimated VND value bought and consumed for prepared food in last 2 weeks			
Lowest quartile			0.004
2nd quartile	1.371 [.795 2.363]	0.257	
3rd quartile	1.761 [1.084 2.862]	0.022	
Highest quartile	2.574 [1.547 4.285]	<0.001	
Estimated VND value bought and spent for index child in presents and treats			
None (reference)			0.026
Lowest spending group	2.734 [.942 7.933]	0.064	

	Middle spending group	2.588 [.924 7.252]	0.070	
	Highest spending group	4.217 [1.520 11.698]	0.006	
	Did child eat sweet, honey, or sugary drinks in the last 24 hours?	1.426 [.965 2.106]	0.075	0.075
	Number of times child ate in the last 24 hours			
	3 times (reference)			<0.001
	4-5 times	1.513 [.775 2.955]	0.225	
	6-7 times	3.234 [1.557 6.718]	0.002	
Physical Activities	**Hours child spent playing/general leisure time in the last week (during the week)**			
	<6 hours (reference)			0.378
	6-10 hours	1.024 [.621 1.297]	0.565	
	10+ hours	.545 [.465 1.140]	0.166	
	Hours child spent in extra class outside of school			
	0 (reference)			<0.001
	1-2 hours	.898 [1.188 2.309]	0.003	
	3+ hours	.728 [.530 1.167]	0.232	
	Transportation to School			<0.001
	Walking (reference)			
	Bike	1.622 [.970 2.712]	0.065	
	Motorbike	3.804 [2.458 5.889]	<0.001	
	Hours child spent studying at home			
	0 (reference)			0.454
	1 hour	1.716 [.730 4.033]	0.216	
	2 hours	1.642 [.696 3.874]	0.257	
	3+ hours	2.175 [.829 5.705]	0.114	
	Child spent time in extra class outside of school in the last 6 months	1.057 [.775 1.442]	0.726	0.726
ROUND 2 (Age 5)				
Child Characteristics	**Hours spent sleeping**			
	10 hours (reference)			0.931
	Less than 10 hours	.954 [.639 1.425]	0.820	
	More than 10 hours	1.042 [.675 1.606]	0.854	
Mother's Characteristics	**Mother's education**			
	No education (reference)			<0.001
	Primary school (grade 1-5)	3.468 [1.023 11.761]	0.046	
	Middle school (grade 6-9)	2.951 [.865 10.063]	0.084	
	High school (10-12)	4.834 [1.337 17.480]	0.016	
	University or Vocation school	10.326 [2.780 38.349]	<0.001	
	Mother's BMI			
	Normal BMI: 18.5 to 23 (reference)			<0.001
	Underweight:	.269 [.115 .629]	0.002	

	<18.50			
	Overweight: >23	2.143 [1.502 3.057]	<0.001	
	Mother's perception of child's weight for overweight and obese children			
	Mother misidentifies child as normal or lighter than average	3.300 [1.517 7.180]	0.003	<0.001
Household Characteristics	**Wealth index**	1.310 [1.241 1.383]	<0.001	<0.001
	Owns a Television	1.958 [.919 4.1741]	0.082	0.082
	Number of Television in household			
	0 (reference)			0.086
	1 TV	1.979 [.928 4.221]	0.077	
	2+ TV	2.808 [1.124 7.0135]	0.027	
Nutrition	**Food diversity: sum of different types of food groups eaten in the last 24 hours (0-14)**	1.332 [1.208 1.469]	<0.001	<0.001
	Number of times child ate within the last 24 hours			
	3 times (reference)			0.002
	4-5 times	1.278 [.694 2.352]	0.430	
	6+ times	2.453 [1.293 4.654]	0.006	
	Estimated VND of powdered/formula milk bought & consumed in last 2 weeks			
	Lowest quartile			<0.001
	2nd quartile	3.061 [1.772 5.289]	<0.001	
	3rd quartile	2.393 [1.396 4.102]	0.002	
	Highest quartile	2.746 [1.626 4.639]	<0.001	
	Estimated VND of sugar/honey bought and consumed in the last 2 weeks			
	Lowest quartile			<0.001
	2nd quartile	2.386 [1.599 3.560]	<0.001	
	3rd quartile	2.560 [1.711 3.830]	<0.001	
	Highest quartile	1.788 [1.141 2.801]	0.011	
	Estimated VND of milk/milk products bought and consumed in the last 2 weeks			
	Lowest quartile (reference)			<0.001
	2nd quartile	1.408 [.771 2.570]	0.265	
	3rd quartile	2.410 [1.437 4.041]	0.001	
	Highest quartile	3.903 [1.437 4.041]	<0.001	
	Estimated VND of prepared foods (restaurant/food stalls) bought and consumed in the last 2 weeks			<0.001
	Lowest quartile (reference)			

	2nd quartile	1.204 [.585 2.47]	0.615	
	3rd quartile	2.579 [1.423 4.661]	0.002	
	Highest quartile	4.606 [2.589 8.194]	<0.001	
Physical Activity	**Transportation to School**			<0.001
	Walking (reference)			
	Bike	1.317 [.796 2.179]	0.283	
	Motorbike	3.262 [2.106 5.0529]	<0.001	
	Hours child spent playing/general leisure time in the last week (during the week)			
	<6 hours (reference)			0.163
	6-10 hours	1.621 [.985 2.667]	0.057	
	>10 hours	1.212 [.691 2.127]	0.502	
	Hours time spent in school during the week			
	5-7 hours (reference)			0.018
	<5 hours	2.234 [1.261 3.956]	0.006	
	>7 hours	1.368 [.779 2.402]	0.276	
ROUND 1 (Age 1)				
Child Characteristics	**Birth weight (grams)**			
	<=2600 grams (reference)			0.029
	>2600 to <3600 grams	1.821 [1.065 3.113]	0.029	
	>=3600 grams	2.375 [1.251 4.510]	0.008	
	Child born premature	1.234 [.798 1.907]	0.344	0.344
	Age order of child			
	No siblings (reference)			0.012
	Youngest child	.608 [.438 .843]	0.003	
	Middle or oldest child	.942 [.069 12.786]	0.964	
	Perception of size at birth			
	Average (reference)			0.043
	Smaller	1.142 [.742 1.757]	0.545	
	Larger	1.707 [1.125 2.591]	0.012	
Mother's Characteristics	**Mother's age (years)**			
	>=24 to <=28 (reference)			<0.001
	<24	.422 [.256 .695]	0.001	
	>28	.799 [.558 1.145]	0.221	
	Mother's happiness	1.512 [1.042 2.193]	0.029	0.029
Household Characteristics	**Number of adults in household**			
	2-3 (reference)			
	3 or more	1.117 [.803 1.554]	0.511	
	Number of children born to mother			
	1 (reference)			0.031
	2 children	.768 [.540 1.093]	0.143	
	3 children	.471 [.258 .858]	0.014	
	4 children	.450 [.186 1.093]	0.078	
	Child has siblings	.667 [.482 .923]	0.014	0.014
	Sibling composition in family			

		Only child (reference)			0.014
		Only girl with male siblings	.290 [.122 .686]	0.005	
		Only male with female siblings	.604 [.360 1.015]	0.057	
		All female family	.937 [.507 1.732]	0.836	
		All male family	.694 [.405 1.188]	0.183	
		Male & female mix family	.497 [.234 1.054]	0.068	
	Number of adults in household caring for child				
		1-2 members (reference)			0.040
		3 members	1.368 [.915 2.044]	0.127	
		4+ members	.750 [.500 1.124]	0.163	
Nutrition	**Length of breast feeding (m)**				
		0-6 months (reference)			0.057
		7-12 months	.341 [.121 .963]	0.042	
		>12 months	.397[.183 .863]	0.020	

[1] *Overall P-value = Pearson's chi-square test*

Table 4.1 - Extended models

	Model 1 (Concurrent - R3)		Model 2 (Early Factors - R2)			Model 3 (R2 & R3 combined)			Model 4 (R1, R2, & R3 combined)			
VARIABLES	1A (n=607) OR (SE)	1B (n=245) OR (SE)	2A (n=1,270) OR (SE)	2B (n=846) OR (SE)	2C (n=846) OR (SE)	3A (n=485) OR (SE)	3B (n=607) OR (SE)	3C (n=420) OR (SE)	4A (n=1,269) OR (SE)	4B (n=1,274) OR (SE)	4C (n=829) OR (SE)	4D (n=1,004) OR (SE)
SOCIAL DEMOGRAPHICS												
Wealth index	1.146*	0.997	1.079	1.255***	1.209***	1.064	1.121	1.236**	1.095*	1.089*	1.088	1.055
	(0.0907)	(0.122)	-0.0537	-0.0887	-0.0856	(0.0886)	-0.0883	-0.124	-0.0535	-0.0535	(0.0789)	(0.0494)
Sex boy (1)	1.996***	1.861	2.934***	2.687***	2.671***	4.036***	2.304***	3.216***	2.850***	2.895***	2.537***	2.537***
	(0.521)	(0.832)	-0.613	-0.622	-0.633	(1.406)	-0.627	-0.989	-0.595	-0.604	(0.743)	(0.594)
Urban (1)	0.149	0.00445**	0.369	0.752	0.816	0.0420*	0.197	0.428	0.428	0.403	0.582	1.130
	(0.221)	(0.0114)	-0.364	-0.853	-0.92	(0.0736)	-0.281	-0.59	-0.411	-0.385	(0.683)	(1.073)
Interaction term	1.286**	1.569**	1.175**	1.124	1.115	1.381**	1.252**	1.139	1.163**	1.162**	1.109	1.092
	(0.146)	(0.311)	-0.0897	-0.0969	-0.0959	(0.184)	-0.137	-0.119	-0.0868	-0.0861	(0.1000)	
ROUND 3 VARIABLES												
Transport to school (motorbike 1)		2.835**				2.533**						
		(1.482)				(1.054)					0.322***	
Sibling BMI (underweight)		0.429*									(0.0951)	
Times eaten >3 (R2)						2.457			2.068**			
		(0.201)				(1.369)			(0.642)			
Value of powder milk	1.732**	1.550					1.471	1.417				
	(0.464)	(0.739)					(0.415)	(0.480)				
Value of packaged sweets	0.917	0.647					0.724	2.097**				
	(0.257)	(0.308)					(0.214)	(0.632)				
Value of eating out	2.224**	6.998**					2.007*	1.120	1.213	1.291	1.512	1.340
	(0.861)	(5.949)					-0.79	(0.370)	(0.294)	(0.314)	(0.560)	(0.378)
ROUND 2 VARIABLES												
Transport to school (motorbike 1)			2.234***	2.505***	2.176***	5.094***		2.854***	2.301***	2.225***	2.257**	
			(0.529)	(0.687)	(0.611)	(2.131)		(1.029)	(0.544)	(0.523)	(0.781)	
Times eaten (>3 times)			1.695	1.857*	1.456	1.551		1.568				
			(0.547)	(0.661)	(0.547)	(0.535)		(0.735)				
Food diversity (high)			1.167**		1.088			1.265		1.431	1.119	
			(0.0757)		(0.0823)			(0.408)		(0.341)	(0.0947)	
Value of powdered milk			1.463		1.296	1.027	1.797*	0.701	1.536*	1.831***	1.178	1.685*
			(0.348)		(0.340)	(0.401)	(0.558)	(0.227)	(0.363)	(0.374)	(0.410)	(0.476)
Value of packaged sweets			1.883***		1.990***	1.474	2.052***	1.608	2.004***	1.377	1.952**	2.094***
			(0.382)		(0.462)	(0.485)	(0.564)	(0.725)	(0.406)	(0.295)	(0.564)	(0.479)
Value of sugar consumption			1.346		1.512*	0.776	1.066		1.382			1.453
			(0.291)		(0.371)	(0.284)	(0.309)		(0.298)			(0.352)
child play (<6 hours)				1.459	1.187							
				(0.519)	(0.433)							
ROUND 1 VARIABLES												
breastfeed <6 months												-0.0787
												0.429
breastfeed >6 months												-0.29
												0.595
premature (yes 1)												-0.28
age mom (<27 years)												
Mom's ed: high school+												2.047**
									0.953			(0.622)
# of adults caring for child									(0.192)			

*p<0.05; **p<0.01; ***p<0.001