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Unhealthy Weight Among Children-Mother Pairs in Cambodian Families: Prevalence and Associated Factors

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B.S.
Purdue University
2020

Thesis Committee Chair: Solveig Cunningham, PhD

An abstract of
A thesis submitted to the Faculty of the
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Abstract

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By Zhiyao Wang

Childhood malnutrition, including underweight, wasted, and stunted, has long been a concern in Cambodia; however, it is unclear how overweight, and obesity affect Cambodian children. In addition, no study was found focused on exploring the weight patterns of mother-child pairs in Cambodia. In this study, four years of Cambodian DHS data (2000 to 2014) were used to understand the prevalence of unhealthy weight and height among children from 2000 to 2014, the prevalence of mother-children weight pairs in 2014, and the characteristics of children and mother-child pairs. Another purpose of this study was to examine the association between individual-and household- level factors and unhealthy weight in children and mother-child pairs. Survey adjusted descriptive analyses were performed for all selected variables: proportion was calculated. Logistic regression was conducted to understand the association between unhealthy weight and individual- and household-level factors among children and mother-child weight pairs. In conclusion, for the last 20 years, Cambodia has reduced both hungry and over-nourished children, as evidenced by a continuous decrease in the prevalence of wasting, underweight, stunting, overweight and obesity. Finally, this study discovered that individual and household level factors such as place of residence, family wealth index, parental education attainment, and birth size are associated with wasted, underweight, stunted children, and unhealthy mother-child weight pairs.

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Chapter 1: Introduction

Retaining a good nutrition status is critical for children. Malnutrition, including undernutrition and overnutrition, can alter children's growth and lead to a higher mortality rate due to its negative effect on muscle, cardiorespiratory, gastrointestinal, immunity, mental, and psychological functions (Saunders & Smith, 2010). Cambodian children's health has improved as a result of multiple nutrition and health programs' implementation (Zanello et al., 2016); however, childhood malnutrition remains an unsolved problem. Recent data reveals that 32% of Cambodian children under the age of 5 were stunted, and 10% were wasted, which are classified as very high and high severities, respectively (Blaney et al., 2019). Family members, especially mothers, play an important role in childhood malnutrition interventions (Liu et al., 2013). The shared genetic background and living environment between parents and children can result in similar weight status (Liu et al., 2013) . In addition, mothers often have a direct impact on their children's food consumption and levels of physical activity, which can affect their child's weight status (Liu et al., 2013). Therefore, the 12% increase in overweight and obese women aged 15-49 in Cambodia from 2000-2014 increased the risk of more children becoming overweight and obese (*Cambodia Nutrition Profiles*; Williams et al., 2014). Aside from sharing similar weight statuses, the double burden of malnutrition has become more prevalent in recent years. A double burden household refers to one in which one or more people have wasting/stunting/underweight and one or more people are overweight or obese (Popkin et al., 2020). Mother-child pair is usually used to determine if a family faces the double burden of malnutrition. For example, overweight mothers with stunted children have been observed in countries in South Asia and Latin American (Nakphong & Beltran-Sanchez, 2021). While the double burden of malnutrition

is commonly considered a problem in high-income countries, it is now becoming a public health issue in many low- and middle-income countries (Popkin et al., 2020).

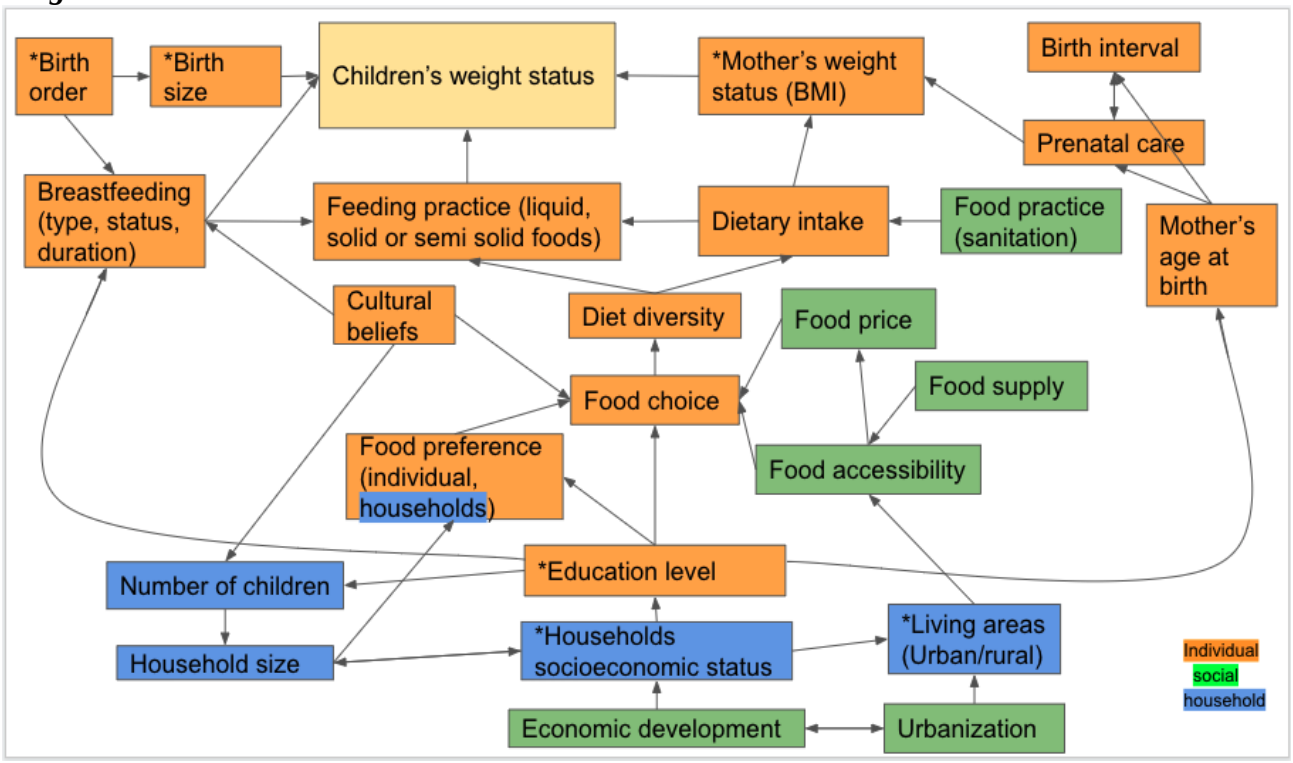
This study will explore the prevalence of unhealthy weight and how unhealthy weight is associated with individual and household-level factors among children under 5 years old in Cambodia. Assessing determinants of unhealthy children's weight will aid in the advancement of future research into nutrition disparities and the establishment of health and nutrition programs that promote good nutrition for children. To demonstrate the discrepancy in children and their mothers' weight status, we categorize child-mother pairs as concordant or discordant weight pairs in this study. Concordant weight pair is when children and mothers share the same weight status of either underweight, normal, or overweight. For the purposes of this study, mothers or children who are obese are grouped with those who are overweight. Discordant weight status pairs will contain mother-child pairs with different weight status, including underweight children with normal or overweight mothers, normal-weight children with under or overweight mothers, and overweight children with under or normal-weight mothers.

The aim of this study is to answer the following questions:

1. What are the prevalence and characteristics of unhealthy weight among children under 5 years old from 2000-2014?
2. What are the prevalence and characteristics of mother-child concordant and discordant weight pairs in 2014?
3. What individual and household level factors are associated with unhealthy weight children?
4. What individual and household level factors are associated with unhealthy weight mother-child pairs?

Below, the figure identifies factors that are related to children's weight. Orange boxes refer to individual level factors, green boxes represent social level factors, and blue boxes indicate household level factors. Boxes with "*" are factors that will be analyzed in this study.

Figure 1: Individual, Household, and Social Level Factors Related to Children's Weight and Height



Note: 1) Orange indicates individual level factors; Green indicates social level factors; Blue indicates household level factors 2) * indicates factors that will be included in this study 3) Children's weight status is the outcome of interest of this study

Chapter 2. Literature Review:

Unhealthy weight affects billions of people globally, with 1.9 billion adults being overweight & obese and 462 million being underweight (*Fact sheets-malnutrition*, n.d.). In 2019, it is estimated that 149 million children under five were suffered from stunted, 45 million experienced wasted, and 38.9 million were overweight & obese (*Fact sheets-malnutrition*, n.d.). According to the Millennium Development Goals report, the underweight children decreased from 25% to 15% since 1990, but the decline is not evenly distributed around the world (Moshi., 2022). Among underweight children, 90% of them come from sub-Saharan Africa and Southeast Asia, which makes underweight an endemic problem (Akombi et al., 2017). Despite Southeast Asia having the lowest rates of overweight and obesity in the world, the trend of their increase in the last 10-15 years is concerning (Mazidi et al., 2018). Unhealthy weight can have a significant impact on physiological functions, potentially increasing morbidity and mortality rates (Saunders & Smith, 2010). Furthermore, the increased morbidity and mortality rates may place added burden on the health-care system and raise personal healthcare costs (Saunders & Smith, 2010).

2.1. Determinations of Undernutrition & Overnutrition:

Undernutrition is defined as insufficient energy or nutrient intake, including macro- and micro-nutrients, to meet the daily needs to remain in good health (Maleta, 2006). Wasting, stunting, and underweight are outcomes of undernutrition and are commonly used as indices to determine children's health status (Maleta, 2006). Wasting refers to "weight for height" that is used to determine children's weight relative to their height (Maleta, 2006). Stunting, height for age, is to describe a child's height based on age (Maleta, 2006). Underweight means "weight for age" that is to define a child's weight according to age (Maleta, 2006). Based on the World

Health Organization (WHO) standards, below -2 Z-scores or lower than 5th percentile on the growth chart defines children as being wasted, stunted or underweight (Maleta, 2006).

Overnutrition is defined as consuming an excessive amount of energy or nutrients, which results in an increase in body fat that is harmful to one's health (Mathur & Pillai, 2019). To define overweight and obesity, body mass index (BMI) is used, which is calculated by body weight divided by height squared (kg/m^2). Based on the CDC criteria, overweight is having BMI between the 85th and 95th percentile on the growth chart, while obesity is at the 95th percentile or greater (*Defining Childhood Weight Status*, 2021). The World Health Organization (WHO) posts a different criterion: for children under 5 years old, overweight is determined as "weight for height" Z score greater than 2 standard deviations, and obesity is having "weight for height" Z score greater than 3 standard deviations (*Obesity and Overweight*, 2021). For children between 5-19 years old, being overweight is defined as "weight for height" greater than 1 standard deviation, and obesity is greater than 2 standard deviations (*Obesity and Overweight*, 2021).

Adult's weight status is fully assessed using body mass index (BMI) cutoffs. The BMI cutoffs listed below are used as international standards (Weir & Jan, 2021):

- Underweight: BMI less than 18.5 kg/m^2
- Normal weight: BMI greater than or equal to 18.5 to 24.9 kg/m^2
- Overweight: BMI greater than or equal to 25 to 29.9 kg/m^2
- Obesity: BMI greater than or equal to 30 kg/m^2

However, there were some discussions about using different BMI cutoffs for Asian populations. Scientific evidence suggests that Asian people have different relationships between BMI, body fat percentage, and health risks than do European people (Consultation, 2004). It is said that Asian people with a high risk of type 2 diabetes and heart disease have lower BMIs

compared to existing WHO international cut-off points (≥25kg/m^2) (Consultation, 2004). BMI cutoffs recommended by the WHO for Asians are shown below (Liabsuetrakul et al., 2011):

- Underweight: BMI less than 18.5 kg/m^2
- Normal weight: BMI greater than or equal to 18.5 to 22.9 kg/m^2
- Overweight: BMI greater than or equal to 23 to 27.5 kg/m^2
- Obesity: BMI greater than 27.5 kg/m^2

Even though new cut-offs were defined, most research studies remained using international BMI cutoffs. In this study, international cutoffs will be used to define Cambodian women's weight status.

2.2. Consequences of Undernutrition & Overnutrition:

Undernutrition is responsible for approximately 45% of deaths among children under 5 (Vassilakou, 2021). Undernutrition can diminish tissues and organs' functions like muscle function, cardiorespiratory function, gastrointestinal function, immunity, and wound healing, and psychosocial effects due to the depletion of body muscle and fat mass caused by long-term insufficient dietary intake (Bhutta et al., 2017; Saunders & Smith, 2010; Ssentongo et al., 2021). Other common consequences include decreased organ mass, diminished cardiac output, decreased intestinal blood flow, the inability of colons, delayed wound healing, and negative psychological effects like depression and anxiety (Saunders & Smith, 2010). Micronutrient malnourishment has been linked to altered immune function, putting children at a higher risk of infectious diseases (Vassilakou, 2021). In addition, multiple studies have observed cognitive defection among malnourished children. More specifically, these studies show that children who were malnourished at a young age have lower cognitive ability than well-nourished children (Kar et al., 2008; Liu et al., 2003).

Maternal undernutrition is found as an underlining cause for 3.5 million deaths and disabilities in low and middle-income countries (Dadi & Desyibelew, 2019). Undernourished mothers are more likely to have a low birth weight, preterm and unsuccessful birth outcomes compared to well-nourished mothers (Dadi & Desyibelew, 2019). In addition, milk biosynthesis is affected by maternal dietary intake during lactation and adipose nutrient storage (Delgado et al., 1982). Thin women are more likely to have a low adipose nutrient store, and their nutrient store will not increase with continuously low dietary intake. Therefore, the nutrients available for milk biosynthesis are low, resulting in decreased milk production. Furthermore, the milk composition, particularly fat, may be lower as a result of the mother's insufficient nutrient storage in the body (Delgado et al., 1982). As a result, infant with undernourished mother will have lower calories and nutrients intake, which will ultimately impair their growth.

Approximately, 39 million children under 5 years old were overweight & obese in 2020 (*Obesity and Overweight*, 2021). The prevalence of overweight & obese children and adolescents has increased from 4% to 18% globally since 1975. While overweight & obesity among children and adolescents are problems in high-income countries, they have become significant issues in many low- and middle-income countries (*Obesity and Overweight*, 2021; Popkin & Slining, 2013). Similar to undernutrition, obesity & overweight are also considered a health burden, as they can lead to a variety of co-morbidities such as cancer, type 2 diabetes, and heart diseases like hypertension, stroke, and congestive heart failure, and gallbladder disease (Djalalinia et al., 2015). Compared with adulthood obesity, childhood obesity is more serious because the risks of most non-communicable diseases resulting from obesity are influenced by the age of onset and the duration of obesity (Wrzosek et al., 2018). In other words, obese children are more likely to stay obese as adults and suffer from various non-communicable diseases like cardiovascular

disease, type 2 diabetes, and cancer in adulthood compared to non-obese children, which can ultimately result in higher premature death and disability (Cercato & Fonseca, 2019; Chobot et al., 2018; Stone et al., 2018).

Being overweight during pregnancy poses a high risk for both women and fetuses, in which mothers may develop gestational diabetes, preeclampsia, heart disease, and hypertension, while the fetus may be stillborn or develop congenital anomalies (Leddy et al., 2008). Additionally, research studies have shown that overweight mothers are more likely to have medical conditions like polycystic ovary syndrome and to experience obstetric complications (Amir & Donath, 2007). Lastly, overweight mothers experience more psychological stress, which can lead to decreased intention and a lower likelihood of breastfeeding (Amir & Donath, 2007).

2.3. Undernutrition and Overnutrition among mothers and children in Cambodia:

Cambodia has been deemed a successful example for reducing childhood stunting by decreasing the rate of stunting from 51% to 34% from 2000 to 2014 (Zanello et al., 2016). Despite the fact that stunting rates have decreased, undernutrition remains a serious problem in Cambodia (Zanello et al., 2016). Based on recent data, 32% of Cambodian children under 5 years old were stunted and 10% were wasted (Blaney et al., 2019). These prevalence rates are determined as very high and high, respectively. While undernutrition remains an unsolved issue, overnutrition is also becoming a growing problem. From 2000 to 2016, the prevalence of overweight among children and adolescents aged 5-19 years old has increased from 3.7% to 13.6% for boys, and 3.3% to 8.6% for girls (*Cambodia Nutrition Profiles*). Maternal weight has been identified as a risk factor of children's weight. Given the 12% increase of overweight & obese women aged 15-49 from 2000 to 2014 in Cambodia, more children are likely are-risk for

developing overweight and obesity (*Cambodia Nutrition Profiles*; Williams et al., 2014). Drinking sugary beverages and eating snack foods are also contributing factors to obesity (Sahoo et al., 2015). In collaboration with the Hellen Keller International Program, researchers discovered that young children in Cambodia consume mass amounts of unhealthy snacks (*HKI Phase I Report: Understanding the consumption of unhealthy snacks among primary school children in Cambodia*, 2020). Among children from 6-23 months, 75% were given healthy or unhealthy snacks, 44% received sweet biscuits and 31-55% consumed sugary/ savory snacks (*Cambodia Nutrition Sensitive School Feeding*, 2020). Concerns about overweight and obesity among young children have grown due to the rising prevalence of maternal obesity and children's consumption of high sugar and fat snacks.

2.4. The Double Burden of Malnutrition:

Nutrition transition can be attributed to the rapid growth of the modern retail and food service sectors, as well as increased agricultural production, urbanization, and technological change (Popkin, 2015). The major changes include an increase in the consumption of high sugar and fat foods, and a decrease in physical activity, which can lead to rising rates of overnutrition in many low-and-middle income countries (Popkin, 2015). In countries where undernutrition and overnutrition coexist, the double burden of malnutrition has become a popular topic (Davis et al., 2020). Among 126 examined countries, 93 experienced the double burden of malnutrition (Popkin et al., 2020). The double burden of malnutrition can occur within individuals, households, and populations levels (Davis et al., 2020). An individual level double burden of malnutrition occurs when a person is overweight or obese and simultaneously suffers from micronutrient deficiency (Huang et al., 2020). Children can be stunted and overweight at the same time, with prevalence rates ranging from <1% in Myanmar to >15% in Albania (Popkin et

al., 2020). A household-level double burden of malnutrition refers to one or more individuals with wasting/stunting/underweight and one or more people experiencing overweight and obesity in the same household (Popkin et al., 2020). It has been observed in developing countries that children suffering from chronic malnutrition share a home with obese mothers (Badiane et al., 2021).

Economic improvement and urbanization play important roles in the nutrition transition (Popkin et al., 2020). Economic progress not only increases food availability, which aids in the reduction of malnutrition, but also increases people's access to processed foods (Popkin et al., 2020). At the same time, urbanization encourages public transportation development, which can reduce people's physical activity levels (Popkin et al., 2020). Women in South and Southeast Asia are now facing the double burden of malnutrition, with underweight and overweight people coexisting in the population (Biswas et al., 2020). In 128 studies that covered about 5 million women who were older than 15 years old, 28% of them were underweight and 17% were overweight in South Asia, while 20% were underweight and 20% were overweight in Southeast Asia (Biswas et al., 2020).

2.5. Characteristics of Cambodia that are relevant to children's growth:

Several factors have been identified that contribute to the improved health of children. Firstly, several nutrition and child health programs have been implemented in Cambodia for the past decade, including the National Nutrition Programme, Micronutrient Intervention Programme, and The Infant and Young Child Feeding Programmes (Zanello et al., 2016). These programs have improved maternal and child health and have had a significant impact on the nutrition environment (Zanello et al., 2016). The reduction of the gender gap in education is also important; more female education has contributed to an increase in breastfeeding and antenatal

care, both of which have benefited children's growth (Zanello et al., 2016). A Cambodian government strategy focused on promoting infant and maternal care through mass media campaigns, community-based health initiatives, and health workers' training has also helped reduce stunting rates (Zanello et al., 2016). In addition, researchers identified that the national strategy might largely contribute to the improved complementary feeding of children aged 6-23 months and the increased deliveries in healthcare facilities (Zanello et al., 2016). Since 2007, public investments such as vouchers for appointments have enabled more pregnant women's access to antenatal care (Zanello et al., 2016).

From 2004 to 2010, Cambodia experienced impressive economic growth, with the poverty rate falling from 53% to 22% (Zanello et al., 2016). The decreased poverty rate increased household wealth, which helped improve dietary diversity of children's diet including increased consumption of animal source food (Zanello et al., 2016). Overall, Ikeda et al. (Ikeda et al., 2013) identified that improved household wealth, parental education, sanitation, birth spacing, and decreased maternal tobacco use have contributed to a reduction in stunting among children in Cambodia. Researchers discovered that maternal best practices such as hospital birth, breastfeeding, prenatal visits, and children's vaccinations, as well as parental characteristics like educational attainment, are important drivers of childhood stunting when comparing rural and urban areas (Ikeda et al., 2013). Specifically, household wealth affects children's health more significantly in urban areas compared to rural areas (Zanello et al., 2016). Lastly, it is important to note that gender has only had a minor impact on children's nutrition status in Cambodia, indicating that discrimination against female children may not be a major issue (Zanello et al., 2016).

2.6. Associated factors of undernutrition:

Contributing factors for undernutrition include the low socioeconomic status of households, low birth weight, low paternal education, lack of access to clean drinking water and sanitation, inadequate exclusive breastfeeding, high birth order, low food availability, limited access to health services, and insufficient energy and micronutrient intake (Hintsa & Gereziher, 2019). In both South and Southeast Asia, young women in rural areas between 15-19 years old who lived in the poorest wealth quintile had a higher prevalence of underweight (Biswas et al., 2020). Research in Pakistan has shown that gender can be another contributing factor, as girls under 5 years are more likely to be underweight than boys (Kumar et al., 2019). In Cambodia, repeated child parasitic infection, poverty, and the nutrient inadequacy of traditional Cambodian diets are major contributors to being underweight (Karpati et al., 2020). A randomized controlled study that was done in the Soth Nikum District in Cambodia has analyzed determinants of undernutrition among children between 6-23 months (Blaney et al., 2019). The results show that stunting is associated with insufficient protein intake, unsafe water resources, and poor sanitation (Blaney et al., 2019). Birth order also has an impact on children's weight, with researchers discovering that if children are born in the third or higher order, they are more likely to be underweight (Kumar et al., 2019). Lastly, research conducted in Ethiopia shows that children who do not meet the minimum dietary diversity score and do not drink safe water are at a high risk of being underweight (Hintsa & Gereziher, 2019).

2.7. Associated factors of overnutrition:

Overnutrition-related factors, on the other hand, are more complex. Commonly, factors such as maternal age, wealth status, education level, number of children, and anemia all play a role in affecting children’s weight (Greffeuille et al., 2016). It is hypothesized that in many low- and middle-income countries, overweight and obesity are more prevalent in low-socioeconomic-

status households due to poor diet quality (Bhurosy & Jeewon, 2014). In other words, children in low-income households have limited access to fresh produce such as fruits, vegetables, and fish, whereas processed foods or convenience store foods high in sugar, fat, and calories are more readily available (Bhurosy & Jeewon, 2014). Increased consumption of high sugar, fat, and calorie foods, combined with a limited intake of fresh foods, resulted in an increased risk of developing overweight and obesity. The inability to afford food, along with limited access to food, places poor people at risk of malnutrition (Dinsa et al., 2012). Other research, however, found that in some low- and middle-income countries, obesity is a problem among wealthy families because they can afford foods that, if consumed in excess, can put them at risk of becoming obese (Dinsa et al., 2012). For example, overweight was more prevalent among children and women in urban areas and those who lived in the wealthiest households in south and southeast Asia (Biswas et al., 2020). In Cambodia, despite overweight primarily affecting the wealthiest maternal population, the prevalence of overweight has rapidly increased in the poorest mothers as well (Greffeuille et al., 2016). With maternal weight being a risk factor for child weight, Cambodian children from both wealthy and impoverished families may at risk of overweight and obese. To our knowledge, there has been limited research on the risk factors of childhood unhealthy weight and height in Cambodia, with no studies focusing on mother-child weight pairs. This study uses Cambodian Demographic and Health Survey data to further understand the nutritional status of Cambodian children.

Chapter 3. Methodology

3.1. Data Source:

Data are extracted from 2000, 2005, 2010, and 2014 Cambodian Demographic and Health Surveys (DHS). Cambodian DHS is a nationally collected dataset implemented by the Directorate General of Health of the Ministry of Health and the National Institute of Statistics of the Ministry of Planning (National Institute of Statistics/Cambodia et al., 2015). The data was collected in Cambodia through questionnaires and biomarker testing, which included complete information on population health. Maternal, and children's health information are collected using interviews, surveys, and physical and biological measurements like anthropometry, hemoglobin, and micronutrient tests (National Institute of Statistics/Cambodia et al., 2015).

The 2000 Cambodian DHS sampling frame came from the Cambodia General Population Census (GPC) master sample developed by the National Institute of Statistics in 1998 (National Institute of Statistics/Cambodia et al., 2001). To achieve the target sample of 15,300 women, 600 villages and 13,044 households were chosen in total (National Institute of Statistics/Cambodia et al., 2001).

The 2005 Cambodian DHS continuously used the 1998 GPC but included a larger sample size (National Institute of Public Health/Cambodia et al., 2006). A total of 13,505 villages were included, of which 1,312 were in urban areas and 12,193 were in rural areas (National Institute of Public Health/Cambodia et al., 2006). 14,243 households and 17,256 women were eligible for interviews (National Institute of Public Health/Cambodia et al., 2006). In the final analysis, 16,823 women and 6,731 men aged 15-49 years old have successfully completed the interviews (National Institute of Public Health/Cambodia et al., 2006).

In 2010 Cambodian DHS, the Cambodia General Population Census (GPC) has been updated by the National Institute of Statistics in 2008 (National Institute of Statistics/Cambodia et al., 2011). 28,764 enumeration areas (EAs) were identified using the updated sampling frame (National Institute of Statistics/Cambodia et al., 2011). There were 4,301 EAs from urban areas and 24,373 EAs from rural areas, with a total of 15,667 households completed the surveys (National Institute of Statistics/Cambodia et al., 2011). Among qualified women and men, 18,853 women and 8,232 men have completed the surveys (National Institute of Statistics/Cambodia et al., 2011).

Similarly, Cambodian General Population Census (GPC) is the sampling frame that was used in 2014, which contained a total of 28,455 enumeration areas (EAs) (National Institute of Statistics/Cambodia et al., 2015). Overall, 4,245 EAs in urban and 24,210 EAs in rural areas were included (National Institute of Statistics/Cambodia et al., 2015). The data were collected in two stages and a total of 15,825 households have been successfully interviewed (National Institute of Statistics/Cambodia et al., 2015). Among interviewed households, 17,578 women and 5,190 men have participated (National Institute of Statistics/Cambodia et al., 2015).

3.2. Study Population:

This study utilizes four years' Cambodia DHS "childbirth/Health" datasets to understand weight and height of children under 5 years old and their mothers in Cambodia. In the sampled households, all children under the age of five, as well as their mothers, had their height and weight recorded using household questionnaires. Among households that have completed the questionnaires, weight and height of children under five years old and their mothers were then measured by trained fieldworkers. An electronic SECA scale was used to measure weight while a measuring board was used for height measurement. Children under 24 months were measured

when they are lying down, while others were measured when standing up. In final analysis, 3,774 children's information was collected in 2000, 3,796 children were included in 2005 dataset, 3,888 children were contained in 2010 dataset, and 4,427 children's information was contained in 2014 dataset.

3.3. Method:

3.3.1. Outcome variables:

Two outcomes of interest in this study are "unhealthy weight and height children" and "mother-child pairs". Both variables are assessed utilizing weight and height data. Five outcome variables are created to assess children's weight and height, which are named "wasted", "underweight", "normal weight", "overweight" and "stunted". These five variables are categorized using the z-score based on the World Health Organization (*World Health Organization Malnutrition*). An underweight child is defined as weight for age with a z score lower than 2 standard deviations, a wasted child is having weight for height with a z score lower than 2 standard deviations, a stunted child is having height for age with a z score lower than 2 standard deviations, and an overweight child is having weight for height with a z score larger than 2 standard deviations (*World Health Organization Malnutrition*).

In the analysis, outcome variables are re-coded from the original DHS variables. "Wasted" is created using variable hw72 (weight/height standard deviation) and categorized as 0 "not wasted" and 1 "wasted". "Underweight", "normal weight" and "overweight" variables are created using variables hw71(weight/age standard deviation) and hw72(weight/height standard deviation). "Stunted" variable is created using original variable hw70 (height/age standard deviation) and categorized as 0 "not stunted" and 1 "stunted". In logistic analysis, "child

underweight" variable was created using variable hw71 (weight/age standard deviation) and categorized as 0 "not underweight" and 1 "underweight".

Mother-child pairs can be defined as either concordant weight pairs or discordant weight pairs. Concordant weight pairs refer to mother and child who has the same weight status, while discordant weight pairs represent mother and child with different weight status. Following the WHO guidelines, mother's weight status is determined using BMI cutoffs through original variable v445 (women body mass index) (Weir & Jan, 2021).

Two outcome variables "healthy mother-child weight pairs" and "unhealthy mother-child weight pairs" are created for logistic regression analysis. "Healthy mother-child weight pairs" variable only includes normal weight mothers & children while "unhealthy mother-child weight pairs" variable includes all other pairs (underweight mothers & children, overweight mothers & children, underweight mothers & overweight children, overweight mothers & underweight children, normal-weight mothers & underweight children, normal-weight mothers & overweight children, underweight mother & normal-weight children, and overweight mother & normal-weight children).

3.3.2. Independent variables:

Independent variables are identified from associated individual and household level factors. Individual-level factors include sex of child, size of child at birth, children's age, birth order, maternal education attainment, and husband's education level. Household-level factors include type of place of residence, family wealth index, and region. Among these factors, birth size, children's age, and maternal education attainment have been re-coded as new variables and have small categories combined to avoid bias. New variable "mother education attainment" is created using variable v149 (maternal educational attainment) and categorized as no education,

incomplete primary, complete primary, incomplete secondary and higher. New variable “birth size” is determined using variable m18 (size of child at birth) and categorized as very large, larger than average, average, and smaller than average. New variable “child age” is created using variable v013 (age in 5-year groups) and categorized as 15-29 and 30-49 months. Lastly, new variable “birth order” is created using variable bord (birth order number) and categorized as first, second and third plus.

Any missing values are recorded as “.” and excluded from the data analysis. The 2014 data has 9 missing maternal weight values, 1 missing birth size value, and 1 missing partner education level value. For mother-child weight pairs, concordant weight pairs have 1,861 missing, while discordant weight pairs have 214 missing. In 2010, there are 118 missing values for birth size and 60 missing values for partner education. There are 103 missing values for partner education and 35 missing values for birth size in the 2005 data. Lastly, there are 42 missing values for partner education and 119 missing values for birth size in the 2000 data.

***3.3.3. Analysis*:**

Four DHS datasets were analyzed using STATA/SE 17 software in this study. Survey weight was adjusted to represent the population of Cambodian children under five years old. Descriptive statistics were performed to understand the proportion and characteristics of children’s different weight and height status and mother-child weight pairs. To answer the third research question, the relationships between outcome (wasted, underweight, stunted) and independent variables (type of place of residence, household wealth index, maternal education attainment, partner’s education level, birth size, maternal weight, birth order, child sex) were assessed using logistic analysis utilizing 2014 and 2010 datasets. Lastly, logistic regression analyses were used to assess the association between mother-child pairs and individual and

households level factors using the 2014 dataset. In analyzing mother-child weight pairs, unhealthy weight pairs (contain at least one member with unhealthy weight) are compared with healthy weight pairs (both mother and child have normal weight). In all analyses, alpha was set at 95% confidence, and p-value <0.05 is considered significant.

4. Results (Survey weight adjusted):

4.1. Descriptive Analysis

4.1.1. The Prevalence and Characteristics of Unhealthy Weight among Children Under 5-year-old from 2000-2014

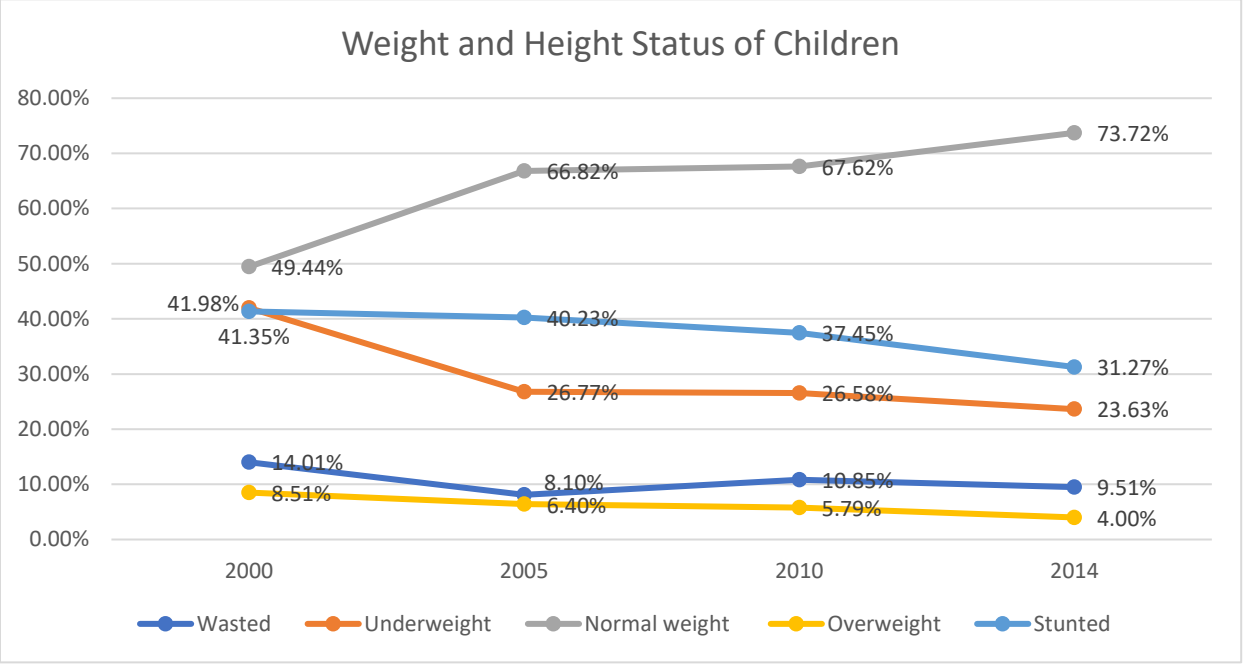
Table 1 and Figure 2 show the results of descriptive analysis of weight and height to answer the question "what is the prevalence of unhealthy weight among children under 5 years old from 2000-2014?". In 2014, after survey adjusted, we found that 4% of children were overweight, 9.51% of children were wasted, 23.63% of children were underweight, 31.27% of children were stunted and 73.72% of children have normal weight. From 2000 to 2014, the majority of children in the population were normal weight, which its prevalence rate increased from 49.44% to 73.72%. The prevalence of underweight and overweight has both reduced, in which underweight children decreased from 41.98% to 23.63%, while overweight children decreased from 8.51% to 4%. In addition, we observed a 10% decrease of stunting rate from 2000 to 2014. Even though the prevalence of stunted children has decreased, stunting is still classified as a very high severity based on the WHO cutoffs (*Nutrition Landscape Information System (NLiS)*). Unlike other unhealthy weights, the prevalence of wasted has not decreased since 2005 and 9.51% of children still suffered from wasting in 2014.

Table 1: 2000-2014 Survey Adjusted Description of Weight and Height Among Children under 5 Years Old

	Wasted	Underweight	Normal weight	Overweight	Stunted
2000	14.01%	41.98%	49.44%	8.51%	41.35%
2005	8.10%	26.77%	66.82%	6.40%	40.23%
2010	10.85%	26.58%	67.62%	5.79%	37.45%
2014	9.51%	23.63%	73.72%	4.00%	31.27%

Note: 1) Based on the WHO definition, child weight status can be assessed using weight for height or weight for age criteria. 2) In "child/health dataset, HW72 is weight by height standard deviation variable. HW71 is weight by age standard deviation variable and HW70 is height by age standard deviation variables. 3) Wasted refers to weight for height (Z score<-2) and is created using HW72 variable. 4) Underweight refers to weight for age (Z score<-2) and is created using HW71 variable. 5) Normal weight refers to weight for age (-2≤Z score<2) and is created using HW71 variable. 6) Overweight refers to weight for height (Z score<-2) and is created using HW72 variable. 7) Stunted refers to height for age (Z score<-2) and is created using HW70 variable. 8) 2014 sample size n= 4,427; 2010 sample size n=3,888; 2005 sample size= 3,796; 2000 sample size=3774. 9) Source: National Institute of Statistics/Cambodia et al., 2015; 2011; 2006; 2001. 10) All results are survey adjusted

Figure 2: Changes of Children's Weight and Height From 2000-2014



Note: 1) Based on the WHO definition, child weight status can be assessed using weight for height or weight for age criteria. 2) In "child/health dataset, HW72 is weight by height standard deviation variable. HW71 is weight by age standard deviation variable and HW70 is height by age standard deviation variables. 3) Wasted refers to weight for height (Z score<-2) and is created using HW72 variable. 4) Underweight refers to weight for age (Z score<-2) and is created using HW71 variable. 5) Normal weight refers to weight for age (-2≤Z score<2) and is created using HW71 variable. 6) Overweight refers to weight for height (Z score<-2) and is created using HW72 variable. 7) Stunted refers to height for age (Z score<-2) and is created using HW70 variable. 8) 2014 sample size n= 4,427; 2010 sample size n=3,888; 2005 sample size= 3,796; 2000 sample size=3774. 9) Source: National Institute of Statistics/Cambodia et al., 2015; 2011; 2006; 2001. 10) All results are survey adjusted

Table 2 provides the results of nutritional status of children by independent variables in sampled households. Beginning with individual characteristics, the prevalence of male and female children was divided equally, with a difference smaller than 5%. Most children were first born children in an average size, but the prevalence of children born in "smaller than average" and "larger than average" remains high. When examining parents' characteristics, mothers in the sampled households primarily lack a primary school education, whereas their partners mostly have a primary or secondary level education. Lastly, children with unhealthy weights and heights were mostly from rural areas, and as household wealth increases, the prevalence of underweight, wasting, and stunting decreases. Aside from children in middle-income households, the prevalence of overweight and obesity remains high in both poor and rich households, with a difference being less than 3%. Kampong Cham region has the highest rate of wasting (12.27 %), underweight (16.71%) and stunting (15.63%) while Phnom Penh has the highest rate of overweight and obese (12.26%). *Figure 3* shows the map of Cambodia, and it indicates that Kampong Cham and Phnom Penh are both province in middle area of Cambodia.

Table 2: Characteristics of Underweight, Normal weight, Overweight&Obese, Wasted and Stunted Children Under Age 5 in Percentage

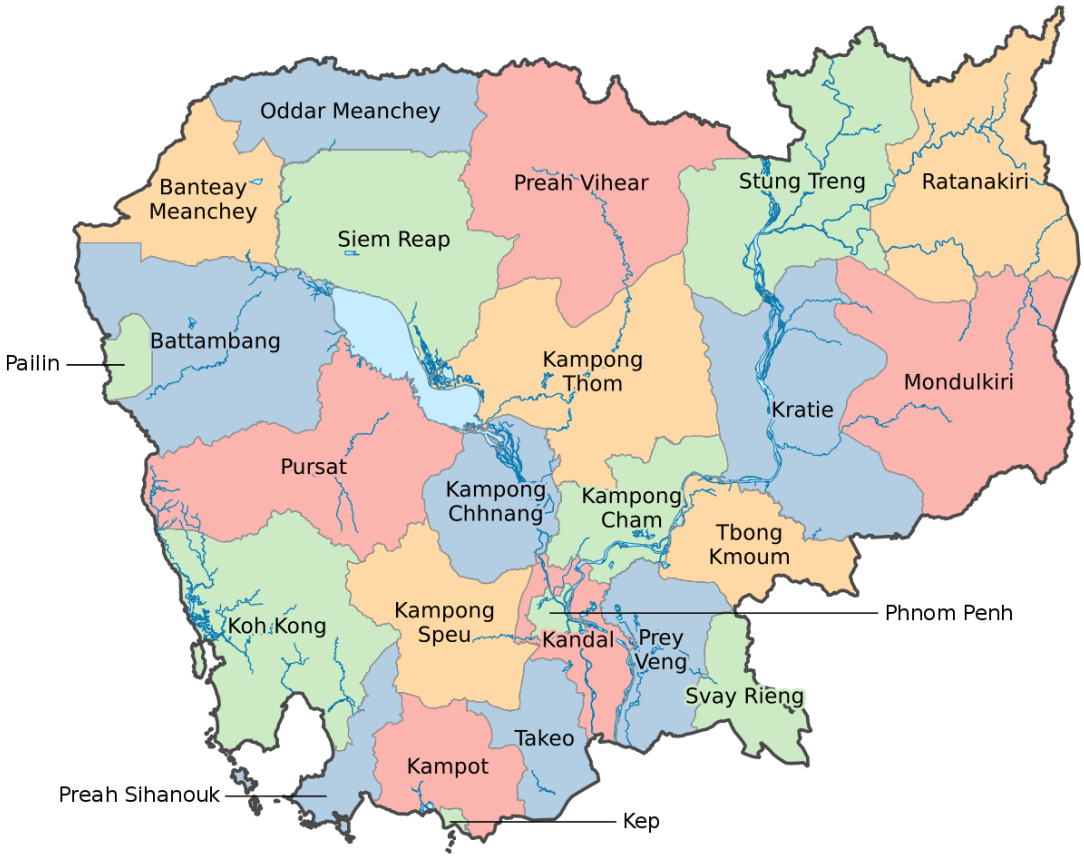
	Underweight	Normal weight	Overweight& obese	Wasted	Stunted
Sample Size N=4,427					
Children's characteristics:					
Sex of child					
Male	48.57	51.30	52.16	51.94	51.47
Female	51.43	48.70	47.84	48.06	48.53
****Size of child at birth***					
Very large	1.16	4.39	3.58	1.68	1.57
Larger than average	22.50	34.74	39.68	22.32	26.32
Average	57.04	52.63	44.05	55.53	56.59
Smaller than average	19.30	8.24	12.69	20.48	15.52
****Age in 5-year groups (months)***					
15-29	56.49	60.65	64.80	58.43	57.66

30-49	43.51	39.35	35.20	41.57	42.34
***Birth order**					
First	39.98	39.28	35.74	39.17	37.17
Second	27.60	30.63	34.29	25.68	28.65
Three plus	32.42	30.10	29.97	35.15	34.18
Parental characteristics:					
***Maternal Education attainment**					
No education	15.87	12.33	16.26	15.77	16.08
Incomplete primary	47.19	42.35	35.41	44.06	47.73
Complete primary	9.02	11.89	13.95	9.16	10.33
Incomplete secondary	25	27.17	24.72	26.90	22.67
Higher	2.92	6.26	9.66	4.11	3.19
***Husband's education level**					
No education	14.64	9.13	11.72	13.10	13.37
Primary	47.70	42.90	42.34	46.94	47.81
Secondary	33.84	41.34	34.21	33.71	34.95
Higher	3.49	6.11	11.73	5.86	3.44
Don't know	0.34	0.51	0	0.40	0.43
Household Characteristics:					
***Type of place of residence**					
Urban	8.78	15.79	19.55	10.36	10.35
Rural	91.21	84.21	80.45	89.64	89.65
***Wealth index combined**					
Poorest	31.98	22.66	19.67	28.12	31.98
Poorer	23.08	18.57	21.64	23.8	22.95
Middle	20	19.34	16.10	18.37	19.59
Richer	14.65	18.10	19.61	15.50	14.56
Richest	10.29	21.33	22.98	14.22	10.93
***Region:**					
Banteay meanchey	2.32	4.04	3.20	3.30	2.94
Kampong cham	16.71	13.61	7.33	12.27	15.63
Kampong chhnang	5.51	2.99	5.41	4.42	4.82
Kampong speu	8.69	6.60	2.80	7.91	8.86
Kampong thom	5.26	4.19	5.20	5.82	5.06
Kandal	6.65	6.42	4.71	6.81	5.17
Kratie	4.00	3.87	0.87	2.86	4.63
Phnom penh	4.51	9.47	12.26	6.44	4.39
Prey veng	6.47	7.25	5.69	6.79	6.60
Pursat	5.32	4.01	9.71	5.36	5.12
Siem reap	7.11	6.34	9.78	6.63	7.45
Svay rieng	2.89	4.01	3.91	2.55	3.75
Takeo	5.24	5.36	9.69	8.19	5.06
Otdar mean chey	1.78	1.65	5.88	2.77	1.81
Battamband & pailin	5.15	7.95	3.11	5.02	5.73
Kampot & kep	3.26	4.11	2.58	3.42	2.76

Preah sihanouk & kauh kong	1.85	2.37	2.07	2.44	2.13
Preah vihear & steung treng	4.14	2.94	3.02	4.54	4.46
Mondol kiri & rattanak Kiri	3.15	2.83	2.79	2.47	3.64

Note: 1) Based on the WHO definition, child weight status can be assessed using weight for height or weight for age criteria. 2) In "child/health dataset, HW72 is weight by height standard deviation variable. HW71 is weight by age standard deviation variable and HW70 is height by age standard deviation variables. 3) Underweight refers to weight for age (Z score<-2) and is created using HW71 variable. 4) Normal weight refers to weight for age (-2≤Z score<2) and is created using HW71 variable. 5)Overweight refers to weight for height (Z score<-2) and is created using HW72 variable. 6) 2014 sample size n= 4,427. 7) Missing values in variables have been adjusted as "." in analysis 8) Source: National Institute of Statistics/Cambodia et al., 2015. 9) All results are survey adjusted 10) * indicates recode variable

Figure 3: Cambodia Map



Note: 1) Source: https://en.wikipedia.org/wiki/Provinces_of_Cambodia

4.1.2. The Prevalence and Characteristics of Mother-child Weight Pairs

In Table 3, among mother-child weight pairs, about half were concordant pairs with normal-weight mothers and children. Normal weight mother with underweight child pair is the second most common type of weight pairs (16.38%). Lastly, 14.29% of weight pairs consist of an overweight mother with a normal weight child.

Table 3: 2014 Survey Adjusted Description of Mother-child Weight Pairs N=4,420

	Mother			
	Underweight	Normal weight	Overweight	Total
Child				
Underweight	4.45	16.38	2.77	23.6
Normal weight	6.93	51.18	14.29	72.39
Overweight	0.31	2.95	0.745	4.00
Total	11.69	70.5	17.81	100

Note: 1) Based on the WHO definition, child weight status can be assessed using weight for height or weight for age criteria. 2) In "child/health dataset, HW72 is weight by height standard deviation variable. HW71 is weight by age standard deviation variable and HW70 is height by age standard deviation variables. 3) Underweight refers to weight for age (Z score<-2) and is created using HW71 variable 4) Normal weight refers to weight for age (-2≤Z score<2) and is created using HW71. 5) Overweight refers to weight for height (Z score>2) and is created using HW72 variable 6) Mothers' weight status is categorized using BMI cutoffs. 7) Mother-child pair number (n= 4,420) 8) Source: National Institute of Statistics/Cambodia et al., 2015. 9) All results are survey adjusted

Tables 4 and 5 provide the characteristics of concordant and discordant mother-child weight pairs. Concordant weight pairs refer to mother-child share same weight status, while discordant weight pairs represent mother-child share different weight status. Underweight pairs were dominantly found in rural areas and in the poorest households where the mothers had only primary education. As the household wealth index rises, so do the number of overweight pairs. The regions with the highest prevalence of underweight pairs were Kampong Cham (14.35%), Kampong Speu (14.48%), and Prey Veng (12.35%) while regions with the highest prevalence of overweight pairs were Kandal (13.47%), Phnom Penh (20.38%), and Takeo (17.44%).

Discordant weight pairs were mainly found in rural and poorer households. Underweight mother and overweight child pairs were mostly found in Pursat (26.11%) and Siem Reap (25.4%) areas. Kampong cham has the highest prevalence of overweight mother and underweight child pairs (21.99%) and normal weight mother and underweight child pairs (16.46%). Kampong Speu has the highest prevalence of underweight mother and normal weight child pairs (12.66%). Overweight mother and normal weight child pairs were mainly found in Kampong Cham (15.98%), Phnom Penh (12.04%), and Battamband & Pailin (11.25%) regions

Table 4: 2014 Survey Adjusted Characteristics of Concordant Weight Mother-child Pairs in Percentage N=2,566

	Concordant Weight Pairs		
	Underweight pairs	Normal weight pairs	Overweight pairs
Children's Characteristics			
****Birth Order***			
First	53.14	40.72	33.02
Second	25.44	30.15	31.35
Three plus	21.42	29.13	35.63
Sex of child			
Male	50.64	51.6	57.11
Female	49.36	48.4	42.89
****Size of child at birth***			
Very large	0	4.021	3.24
Larger than average	22.75	34.63	47.11
Average	58.75	52.45	43.92
Smaller than average	18.49	8.90	5.73
Age in 5-year groups(months)			
15-29	64.54	61.85	41.18
30-49	35.46	38.15	58.82
Parental Characteristics			
****Maternal Education attainment***			
No education	13.13	11.77	5.87
Incomplete primary	48.01	41.30	48.75
Complete primary	8.72	12.88	4.43
Incomplete secondary	26.36	27.94	19.39
Higher	3.79	6.12	21.56
Husband's education level			
No education	14.11	8.45	12.01
Primary	42.98	42.8	42.02
Secondary	34.90	41.60	27.07

Higher	7.93	6.54	18.91
Don't know	0.08	0.61	0
Household Characteristics			
Type of place of residence			
Urban	5.27	15.77	32.22
Rural	94.73	84.23	67.76
Wealth index combined			
Poorest	30.29	23.5	20.34
Poorer	25.48	18.26	13.50
Middle	23.16	18.31	12.84
Richer	10.95	18.66	26.70
Richest	10.11	21.27	26.63
Region			
Banteay mean chey	2.18	3.7	0
Kampong cham	14.35	13.56	3.84
Kampong chhnang	4.15	3.15	8.90
Kampong speu	14.48	6.36	1
Kampong thom	5.47	4.49	3.01
Kandal	8.33	6.81	13.47
Kratie	4.15	3.88	1.89
Phnom penh	2.62	9.04	20.38
Prey veng	12.35	7.43	0.72
Pursat	3.40	4.43	3.27
Siem reap	4.42	5.99	10.61
Svay rieng	2.87	4.28	0.43
Takeo	3.72	5.23	17.44
Otdar mean chey	1	1.75	5.82
Battamband & pailin	2.35	7.19	4.73
Kampot & kep	5.96	4.46	0
Preah sihanouk & kauh kong	1.77	2.45	0.51
Preah vihear & steung treng	3.09	3.00	0.76
Mondol kiri & rattanak Kiri	3.36	2.81	3.22

Note: 1) * indicates recode variables 2) Underweight pairs include underweight mothers (V445<1850) (BMI<18.5kg/m^2) and children (hw71<-200) (Z score<-2). 3) Normal weight pairs include normal weight mother (1850≤445≤2499) (BMI:18.5-24.99 5kg/m^2) and children (-200≤hw71≤200) (-2≤Z score<2). 4) Overweight pairs include overweight mother (v445>2499) (BMI>24.99kg/m^2) and children (hw72>200) (Z score>2) 5) Mother-child pair number (n= 2,566) 6) Missing values in variables have been adjusted as "." in analysis 7) Source: National Institute of Statistics/Cambodia et al., 2015. 8) All results are survey adjusted

Table 5:2014 Survey Adjusted Characteristics of Discordant Weight Mother-child Pairs in Percentage N=1,864

	Discordant Weight Pairs					
	UMOC	OMUC	NMUC	NMOC	UMNC	OMNC
Children's Characteristics:						
****Birth order***						
First	29.31	29.39	28.2	37.38	49.67	28.99
Second	40.96	17.57	29.88	33.83	30.78	32.29
Three plus	29.73	53.04	31.93	28.78	19.55	38.73
Sex of child						
Male	46.24	38.51	49.7	51.18	47.97	51.85
Female	53.76	61.49	50.3	48.82	52.03	48.15
****Size of child at birth***						
Very large	0	1.23	1.45	4.08	3.28	6.27
Larger than average	12.93	28.12	21.51	41	28.74	38.05
Average	68.84	50.95	57.58	41.01	57.89	50.73
Smaller than average	18.24	19.7	19.45	13.91	10.09	4.95
Age in 5-year groups(months)						
15-29	69.38	36.88	57.62	70.06	77.75	47.99
30-49	30.62	63.12	42.38	29.94	22.25	52.01
Parental Characteristics:						
****Maternal Education attainment***						
No education	40.47	18.96	16.09	16.44	14.62	13.29
Incomplete primary	37.62	44.96	47.35	32.04	38.1	48.19
Complete primary	0	11.76	8.64	17.97	12.31	8.11
Incomplete secondary	12.29	23.69	24.85	27.6	29.24	23.39
Higher	9.62	0.66	3.07	5.96	5.72	7.02
Husband/partner's education level						
No education	26.54	14.7	14.78	10.14	11.92	10.26
Primary	50.34	43.69	49.65	41.88	47.6	40.98
Secondary	20.78	39.95	32.52	37.73	34.38	43.77
Higher	2.33	1.66	2.59	10.25	6.1	4.56
Don't know	0	0	0.46	0	0	0.43
Household Characteristics:						
Type of place of resident						
Urban	3.424	12.03	9.19	17.44	11.44	17.95
Rural	96.58	87.97	90.81	82.56	88.56	82.05
Wealth index combined						
Poorest	19.3	19.61	34.52	19.68	32.09	15.05
Poorer	44.14	29.22	21.39	21.47	17.41	20.22

Middle	17.16	15.78	19.85	16.94	18.45	23.54
Richer	16.59	17.25	15.22	18.27	17.07	16.57
Richest	2.81	18.15	9.02	23.64	14.99	24.62
Region						
Banteay mean chey	0	3.15	2.23	4.38	3.11	5.71
Kampong cham	6.48	21.99	16.46	9.05	0.01	15.98
Kampong chhnang	9.76	5.2	5.93	4.45	2.62	2.59
Kampong speu	0	2.89	8.09	2.53	12.66	4.53
Kampong thom	0	4.14	5.4	6.35	2.89	3.75
Kandal	0	7.61	6.04	3.02	7.15	4.63
Kratie	0	2.6	4.2	0.71	6.02	2.78
Phnom penh	0	0.5	5.69	11.6	7.42	12.04
Prey veng	0	1.19	5.77	7.61	6.69	6.87
Pursat	26.11	8.84	5.25	9.67	3.33	2.81
Siem reap	25.4	13.1	6.82	7.22	8.63	6.49
Svay rieng	0	3.96	2.72	5.24	2.58	3.70
Takeo	8.87	5.49	5.61	7.87	4.77	6.08
Otdar mean chey	5.74	1.11	2.1	5.95	2.04	1.1
Battamband & pailin	0	8.58	5.33	3.06	6.91	11.25
Kampot & kep	0	1.71	2.78	3.53	4.13	2.87
Preah sihanouk & kauh kong	0	3.79	1.54	2.71	2.19	2.15
Preah vihear & steung treng	0	2.33	4.73	3.95	5.2	1.62
Mondol kiri & rattanak kiri	17.64	1.84	3.32	1.11	2.58	3.03

Note: 1) * indicates recode variables 3) UMOC refers to underweight mother (v445<1850) (BMI<18.5kg/m^2) and overweight children (hw72>200) (Z score>2). OMUC refers to overweight mother (v445>2499) (BMI>24.99kg/m2) and underweight child (hw71<-200) (Z score<-2). NMUC refers to normal weight mother (1850≤445≤2499) (BMI:18.5-24.99 5kg/m^2) and underweight children (hw71<-200) (Z score<-2). NMOC refers to normal weight mother (1850≤445≤2499) (BMI:18.5-24.99 5kg/m^2) and overweight children (hw72>200) (Z score>2). UMNC refers to underweight mother (v445<1850) (BMI<18.5kg/m^2) and normal weight children (-200≤hw71≤200) (-2≤Z score<2). OMNC refers to overweight mother (v445>2499) (BMI>24.99kg/m2) and normal weight children (-200≤hw71≤200) (-2≤Z score<2). 4) Mother-child pair number (n= 1,846) 5) Missing values in variables have been adjusted as "." in analysis 6) Source: National Institute of Statistics/Cambodia et al., 2015. 7) All results are survey adjusted

4.2. Logistic Regression Analysis

4.2.1. The Individual and Household Level Factors that are Associated with Unhealthy Weight Children

Tables 6 and 7 show the results of logistic regression analysis of wasted vs. not wasted children, underweight vs. not underweight children, and stunted vs. not stunted children utilizing the 2010 and 2014 data. In analysis, not wasted, not underweight, and not stunted children are coded as "0", while wasted, underweight, and stunted are coded as "1". In 2014, it is found that children who lived in rural areas were 49%, 97%, and 66% more likely to be wasted, underweight, and stunted compared to children living in rural areas (AOR: 1.49, 1.97, and 1.66, respectively). Consistently in 2010 data, children who lived in urban areas have lower odds of being underweight and stunted. For household wealth index, the trend is clear in 2014 data that once the wealth index increase, the odds of children being wasted, underweight and stunted decrease. In 2010, children in the richest households have been the least likely to be stunted (AOR: 0.44), whereas children in the poorest households were 53% more likely to be stunted (AOR: 1.53). With an increased mothers' and their partners' education level, the odds of children being wasted, underweight and stunted decrease. Birth size and birth order also play roles in affecting children's weight status. Children that were born smaller than average or very small were more likely to be wasted, underweight, and stunted when they grow up compared to children born in average or above-average size. A P-value larger than 0.05 indicates there is no significant relationship in weight status between a first-born child and a second-born child. However, in 2014, compared to children born first, children who were born in equal to or greater than three are significantly associated with 1.27 times the odds of being stunted to stunted. In other words, a higher birth order reveals a higher chance of being stunted (AOR: 1.27).

Table 6: 2014 Survey Adjusted Logistic Analysis of Nutritional Status of Children Under 5-year-old in Cambodia, N=4,427

	Wasted		Underweight		Stunted	
2014	OR	95% CI	OR	95% CI	OR	95% CI
Household Characteristics						
Type of place of residence						
Rural	1.49	(1.11, 2.00)	1.97	(1.55, 2.54)	1.66	(1.33, 2.07)
Urban	ref		ref		ref	
Wealth index combined						
Poorest	1.47	(1.12, 1.92)	1.36	(1.04, 1.79)	1.22	(0.82, 1.82)
Poorer	1.24**	(0.95, 1.61)	1.18**	(0.88, 1.58)	1.31**	(0.88, 1.94)
Middle	ref		ref		ref	
Richer	0.77**	(0.59, 1.02)	0.78**	(0.57, 1.06)	0.94	(0.62, 1.43)
Richest	0.48	(0.36, 0.64)	0.46	(0.34, 0.63)	0.78	(0.52, 1.17)
Parental Characteristics:						
****Education attainment***						
No education	ref		ref		ref	
Incomplete primary	0.85**	(0.56, 1.28)	0.89**	(0.66, 1.20)	0.87**	(0.67, 1.13)
Complete primary	0.66**	(0.39, 1.15)	0.6	(0.40, 0.90)	0.67	(0.48, 0.94)
Incomplete secondary	0.84**	(0.52, 1.38)	0.73**	(0.54, 1.01)	0.6	(0.45, 0.80)
Higher	0.59**	(0.31, 1.10)	0.36	(0.21, 0.59)	0.35	(0.23, 0.55)
Husband/partner's education level						
No education	ref		ref		ref	
Primary	0.84**	(0.84, 1.70)	0.7	(0.52, 0.94)	0.78**	(0.59, 1.02)
Secondary	0.66	(1.03, 2.72)	0.52	(0.39, 0.70)	0.59	(0.44, 0.77)
Higher	0.81**	(0.70, 2.15)	0.35	(0.21, 0.58)	0.36	(0.23, 0.57)
****Women weight***						
Underweight	2.42	(1.76, 3.33)	2.02	(1.56, 2.62)	1.57	(1.22, 2.03)
Normal weight	ref		ref		ref	
Overweight	0.87**	(0.61, 1.24)	0.61	(0.46, 0.79)	0.75	(0.58, 0.96)
Children's Characteristics:						
****Size of child at birth***						
Very large	0.42	(0.19, 0.91)	0.24	(0.10, 0.56)	0.31	(0.19, 0.51)
Larger than average	0.65	(0.45, 0.92)	0.59	(0.48, 0.73)	0.7	(0.59, 0.84)

Average	ref		ref		ref	
Smaller than average	1.96	(1.39, 2.75)	2.09	(1.61, 2.71)	1.59	(1.23, 2.05)
***Birth order**						
First	ref		ref		ref	
Second	0.84**	(0.61, 1.18)	0.88**	(0.69, 1.10)	1.01**	(0.84, 1.21)
Three plus	1.17**	(0.87, 1.57)	1.05**	(0.84, 1.33)	1.27	(1.05, 1.55)
Sex of child						
Male	ref		ref		ref	
Female	0.94**	(0.72, 1.23)	1.11**	(0.93, 1.33)	0.95**	(0.80, 1.12)

Note: 1) * indicates recode variables 2) Based on the WHO definition, child weight status can be assessed using weight for height or weight for age criteria. 3) In "child/health dataset, HW72 is weight by height standard deviation variable. HW71 is weight by age standard deviation variable and HW70 is height by age standard deviation variables. 4) Wasted refers to weight for height (Z score<-2) and is created using HW72 variable from "child/health" dataset. 5) Underweight refers to weight for age (Z score<-2) and is created using HW71 variable from "child/health" dataset. 6) Stunted refers to height for age (Z score<-2) and is created using HW70 variable from "child/health" dataset. 7) Children number (sample size n= 4,427) 8) Missing values in variables have been adjusted as "." in analysis 9) ** indicates p-value>0.05 10) Source: National Institute of Statistics/Cambodia et al., 2015. 11) All results are survey adjusted

Table 7: 2010 Survey Adjusted Logistic Analysis of Nutritional Status of Children Under 5-year-old in Cambodia, N=3,888

	Wasted		**Underweight**		**Stunted**	
2010	OR	95% CI	OR	95% CI	OR	95% CI
Household Characteristics						
Type of place of residence						
Rural	0.99**	(0.72, 1.35)	1.89	(1.49, 2.40)	1.93	(1.56, 2.39)
Urban	ref		ref		ref	
Wealth index combined						
Poorest	1**	(0.68, 1.47)	1.38	(1.05, 1.82)	1.53	(1.19, 1.96)
Poorer	0.79**	(0.54, 1.16)	1.31	(0.99, 1.73)	1.24**	(0.97, 1.58)
Middle	ref		ref		ref	
Richer	0.98**	(0.65, 1.46)	0.83**	(0.60, 1.14)	0.85**	(0.64, 1.11)
Richest	0.8**	(0.53, 1.22)	0.47	(0.33, 0.68)	0.44	(0.32, 0.59)
Parental Characteristics:						
***Education attainment**						
No education	ref		ref		ref	
Incomplete primary	1.02**	(0.76, 1.37)	0.79**	(0.62, 1.0)	0.78	(0.63, 0.96)
Complete primary	1.05**	(0.60, 1.83)	0.69**	(0.47, 1.01)	0.69	(0.50, 0.96)

Incomplete secondary	0.89**	(0.60, 1.33)	0.59	(0.43, 0.80)	0.59	(0.45, 0.77)
Higher	0.52**	(0.26, 1.04)	0.21	(0.10, 0.43)	0.18	(0.09, 0.35)
Husband/partner's education level						
No education	ref		ref		ref	
Primary	0.95**	(0.61, 1.49)	0.81**	(0.62, 1.06)	0.85**	(0.68, 1.07)
Secondary	0.88**	(0.57, 1.37)	0.51	(0.38, 0.68)	0.51	(0.40, 0.66)
Higher	1.01**	(0.52, 1.93)	0.38	(0.21, 0.68)	0.23	(0.13, 0.40)
****Women weight***						
Underweight	1.68	(1.23, 2.29)	1.45	(1.15, 1.84)	1.24	(1.01, 1.54)
Normal weight	ref		ref		ref	
Overweight	0.62**	(0.32, 1.20)	0.77**	(0.55, 1.09)	0.82**	(0.61, 1.10)
Children's Characteristics:						
****Size of child at birth***						
Very large	0.61**	(0.31, 1.22)	0.45	(0.30, 0.69)	0.47	(0.32, 0.70)
Larger than average	0.65	(0.47, 0.89)	0.59	(0.48, 0.72)	0.67	(0.56, 0.81)
Average	ref		ref		ref	
Smaller than average	1.61	(1.10, 2.37)	1.61	(1.21, 2.13)	1.61	(1.21, 2.13)
****Birth order***						
First	ref		ref		ref	
Second	0.98**	(0.73, 1.33)	0.98**	(0.81, 1.19)	0.96**	(0.70, 1.16)
Three plus	0.9**	(0.67, 1.21)	1.12**	(0.92, 1.36)	1.37	(1.12, 1.66)
Sex of child						
Male	ref		ref		ref	
Female	0.95**	(0.76, 1.18)	1.02**	(0.86, 1.22)	0.85	(0.74, 0.99)

Note: 1) * indicates recode variables 2) Based on the WHO definition, child weight status can be assessed using weight for height or weight for age criteria. 3) In "child/health dataset, HW72 is weight by height standard deviation variable. HW71 is weight by age standard deviation variable and HW70 is height by age standard deviation variables. 4) Wasted refers to weight for height (Z score<-2) and is created using HW72 variable from "child/health" dataset. 5) Underweight refers to weight for age (Z score<-2) and is created using HW71 variable from "child/health" dataset. 6) Stunted refers to height for age (Z score<-2) and is created using HW70 variable from "child/health" dataset. 7) Children number (sample size n= 3,888) 8) Missing values in variables have been adjusted as "." in analysis 9) ** indicates p-value>0.05 10) Source: National Institute of Statistics/Cambodia et al., 2011. 11) All results are survey adjusted

4.2.2. The Individual and Household Level Factors that are Associated with Unhealthy Mother-child Weight Pairs

Table 8 shows the survey adjusted logistic regression analysis of mother-child weight pairs. Concordant and discordant weight pairs with at least one person being unhealthy weight were grouped together as "unhealthy weight pairs" and compared to the ideal weight pairs (normal weight mother and children). The result reveals that rural areas have higher odds of containing unhealthy weight pairs (AOR:1.31). The odds of containing one unhealthy weight household member decrease when household income increases. For example, comparing to middle wealth index households, poorest households are 7% more likely to contain unhealthy weight pairs while richest households are 32% less likely to contain unhealthy weight pairs. Similarly, households with higher educated mothers and husbands have decreased risk of containing unhealthy weight pairs. Size of the child at birth is also significantly associated with mother-child pair, in which children born smaller than average have higher odds of being in unhealthy weight pairs compared to children born in average size (AOR: 1.45). Children who were born in equal to or greater than three were 19% higher odds of being unhealthy weight pairs than first born children (AOR: 1.19). Lastly, it is found that girls are more likely to be in the unhealthy weight pairs than boys (AOR: 1.07).

Table 8: Survey Adjusted Logistic Regression Analysis of Mother-child Pairs in Cambodia N= 4,420

	Unhealthy weight pairs	
	OR	95% CI
Household Characteristics		
Type of place of residence		
Rural	1.31	(1.10, 1.56)
Urban	ref	
Wealth index combined		
Poorest	1.07**	(0.84, 1.36)
Poorer	1.02**	(0.79, 1.32)
Middle	ref	
Richer	0.77	(0.61, 0.98)
Richest	0.68	(0.54, 0.86)
Parental Characteristics		
****Education attainment***		
No education	ref	
Incomplete primary	0.86**	(0.67, 1.12)
Complete primary	0.59	(0.42, 0.83)
Incomplete secondary	0.7	(0.54, 0.92)
Higher	0.64	(0.45, 0.91)
Husband/partner's education level		
No education	ref	
Primary	0.69	(0.53, 0.90)
Secondary	0.58	(0.45, 0.75)
Higher	0.48	(0.33, 0.70)
****Size of child at birth***		
Very large	0.83	(0.50, 1.13)
Larger than average	0.83	(0.70, 0.98)
Average	ref	
Smaller than average	1.45	(1.12, 1.88)
****Birth order***		
First	ref	
Second	1.08	(0.91, 1.27)
Three plus	1.19	(0.97, 1.45)
Sex of child		
Male	ref	
Female	1.07	(0.92, 1.25)

Note: 1) * indicates recode variables 2) Unhealthy weight pairs include at least one member (mother or child) has unhealthy weight 3) Mother-child pair number (n= 4,420) 4) Missing values in variables have been adjusted as "." in analysis 5) Source: National Institute of Statistics/Cambodia et al., 2015. 6) All results are survey adjusted 7) ** indicates p-value>0.05

5. Discussion:

The study set out 4 questions to understand the nutritional status of children under 5 years old, the patterns of mother-child weight pairs, and their associated factors. Four child health datasets, including the Cambodia DHS from 2000, 2005, 2010, and 2014, were used to examine the distribution of children's weight and height status. Overall, we see a decrease in unhealthy weight and height and an increase in normal weight among children from 2000 to 2014.

Surprisingly, the results show a continuous decrease in overweight and obese children from 8.51% to 4%. According to WHO cutoffs, overweight (4%) is a low problem, indicating that childhood overweight is not a significant problem in Cambodia. This discovery explains why there has been so little research on overweight and obesity in children under the age of five. A possible explanation for this might be that increased implementation of nutrition programs helped improve diet diversity and nutrition environment (Zanello et al., 2016), in which children ate a more balanced diet and decreased consumption of high sugar and calorie foods. Another reason for the decrease in unhealthy weight and height could be that both mothers' and their husbands' education levels have increased since 2000. In appendices, figure 1 shows that mothers who have completed higher education increased from 0.87% to 5.65%, while mothers with no education decreased from 31.96% to 13.35%. As for their husbands, people that have completed higher education increased from 0.91% to 5.65% and no education decreased from 17.5% to 10.52%.

Even though stunted has been reduced from 41.35% to 31.27%, it remains the most critical problem for children in Cambodia. This result is likely to be related to the continuous low protein intake (Blaney et al., 2019). Figure 2 in appendices shows that the consumption of animal-based protein foods hasn't changed since 2000 and there was a decreased consumption of

plant-based protein food. Dietary intake has a direct impact on children's nutritional status; therefore, future studies on the food intake and eating habits topics are recommended.

Using the 2014 dataset, this study examines the nutritional status of children and discovers that the difference between male and female children's nutritional status varies by less than 5%. This finding supports the idea of the previous finding that gender has a minor impact on children's nutrition status (Zanello et al., 2016). The prevalence of unhealthy weight and height does not differ significantly across most regions; however, as two connected provinces in central Cambodia, Kampong cham region experienced the highest undernutrition rate while Phnom Penh experienced the highest overnutrition rate. It is striking that kampong cham region has a 2 to 8 times higher prevalence of underweight, wasting, and stunting compared to other regions. Similarly, Phnom Penh has 2 to 6 times higher prevalence of overweight and obesity than other regions. 2016 Hellen Keller program research discovered that children in Phnom Penh region from 6-23 months have a high snack consumption (Pries et al., 2016), which helped explain the finding that Phnom Penh has a higher prevalence of overweight & obese children compared to other regions. In addition, children in Phnom Penh, Cambodia's capital, may come from higher income families and their greater ability to afford food may explain the higher prevalence of overnutrition. However, no studies have been identified that explain why there is such a high prevalence of undernutrition in Kampong Cham province. Further research should be undertaken to investigate how demographic factors influence children's weight and height, as well as methods to mitigate their impact on children's nutritional status.

Associated individual and household level factors are assessed through logistic regression analysis. Wasted, underweight, and stunted children are significantly related to risk factors such as place of residence, household wealth, parental education attainment, maternal weight, and

socioeconomic status. Using the 2010 and 2014 datasets, the results indicate individual and household level factors that affected children's weight and height status have not changed. In line with previous findings, children from urban areas and wealthier households are less likely to be wasted, underweight, or stunted than children from rural or poorer households (Hintsa & Gereziher, 2019). Also, this study confirms that in Cambodia, with increased parental education levels, the odds of having an unhealthy weight and height decrease (Ikeda et al., 2013). Consistent with the literature (Kumar et al., 2019), this research shows that childbirth size is significantly related to children's weight and height status. A previous study indicated that a lower birth weight increases the likelihood of children being underweight (Kumar et al., 2019). Further, our study's results confirmed that a lower birth weight also increases the likelihood of childhood wasting and stunting.

Previous study has suggested that higher birth order impacts children's weight and is related to children's underweight (Kumar et al., 2019). This does not appear to be the case in this study, where birth order is only found to be significantly associated with stunted and has no relationship with weight status. Birth order is shown an insignificant relationship with weight status may be due to the combination of a wide range of birth orders from 3 to 14 and the limited sample size for each order. Even though the overall relationship is insignificant, the result (*Table 4 and 5*) does show children born in birth orders equal to or greater than three have a higher risk of being wasted, underweight and stunted (AOR: 1.17, 1.05, and 1.27, respectively). In other words, children with higher birth order are more likely to have unhealthy weight and height compared to the firstborn.

Mother-child pairs have been examined through descriptive and logistic regression analysis. The majority of mothers and children were normal weight, or at least one of them was. Popular

weight pairs include “underweight children & normal weight mother” (16.38%) and “normal weight children & overweight mother” (14.29%). The findings confirm that being underweight is the main problem for children, while overweight is the main problem for mothers. Double burden households were less than 5%, which explains why few studies were found related to the dual nutrition burden. Even though the prevalent of double burden household is very low, we found that the double burden weight pairs, overweight mother & underweight children and overweight children& underweight mother, are mainly prevalent in poorer households in Pursat, Siem reap and Kamong cham regions. In general, the study indicates type of place of residency, family wealth index, parental education attainment, birth size, birth order and sex of child are associated with unhealthy mother-child weight pairs.

This study contributes to existing knowledge of children’s health by providing a more in-depth examination of Cambodian children's nutritional status. Four years’ datasets were utilized, and the trend of changing has been identified. Using national survey data and a survey-adjusted analysis method, this result is generalizable to Cambodian children under the age of five. Mother-child pairs are created and descriptively and logistically analyzed, which have not previously been done in Cambodian studies. The study analyzed the distribution of mother-child pairs and used logistic regression to confirm that the unhealthy mother-child weight pairs are associated with individual- and household-level factors in Cambodia. Lastly, children and their mothers’ weight and height data were measured through field workers, which helped eliminate the report errors.

In terms of limitations, logistic regression analysis only classified children’s weight status into two categories in this study. Due to the fact that the number of overweight and obese children is little, we combined normal weight and overweight to avoid bias. However, combining

normal weight with overweight can lead to one category having a lot larger population size than the other one, which may lead to inaccurate results in analysis. In the future study, three categorizations (underweight, normal, and overweight) are expected to be used for understanding a more accurate association. Finally, only protein-sourced foods were considered when investigating complementary feeding, whereas all foods should be considered to gain a more comprehensive understanding of child feeding.

This study has explored the problem of unhealthy weight and height in Cambodian children under the age of five and examined the weight status of mother-child pairs. The increased prevalence of children of normal weight indicates the success of Cambodia's health and nutrition strategy. However, undernutrition among children under 5 years old remains a problem in Cambodia and required further action. The results have also proven the importance of individual and household level factors in Cambodian children's weight status. The weight of the mother influences the weight of her children is confirmed, but the role of the father's weight is unknown. Future studies into the relationship between father and child weight are therefore recommended. In addition, as overweight and obesity become more prevalent among mothers, future research can focus more on nutrition transition in families and how this may affect children's health. Given the importance of parental education attainment in children's weight status, national strategy, programs, and practices should emphasize parental role in children's health development and consider addressing parents' nutrition education. In addition, unhealthy weight, and height status (wasting, underweight, overweight & obese and stunting) are determined based on Z-score cutoffs, in which a little above or below the cutoff can be categorized differently. Future research should focus on understanding how extreme unhealthy weight status changed in Cambodia and how risk factors contributed to it. Nutrition improvement programs are constantly

evolving and improving all over the world, particularly in low- and middle-income countries. As childhood wasted, underweight, and stunted remain unsolved problems in Cambodia, national nutrition programs or practices in Cambodia should continue refining in the future.

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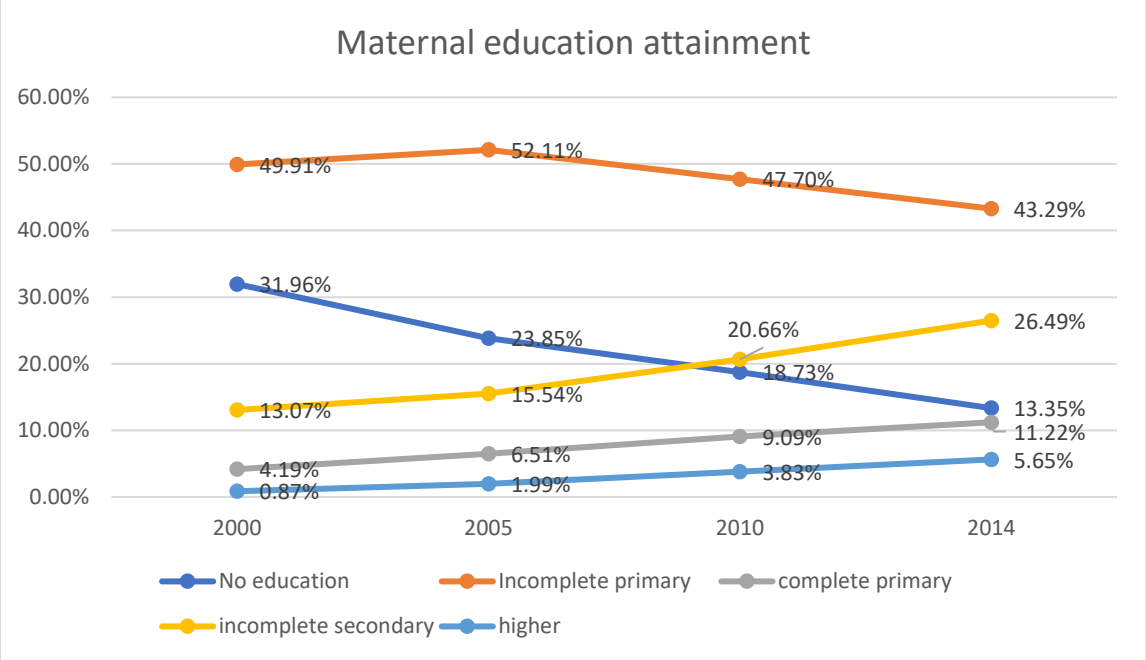
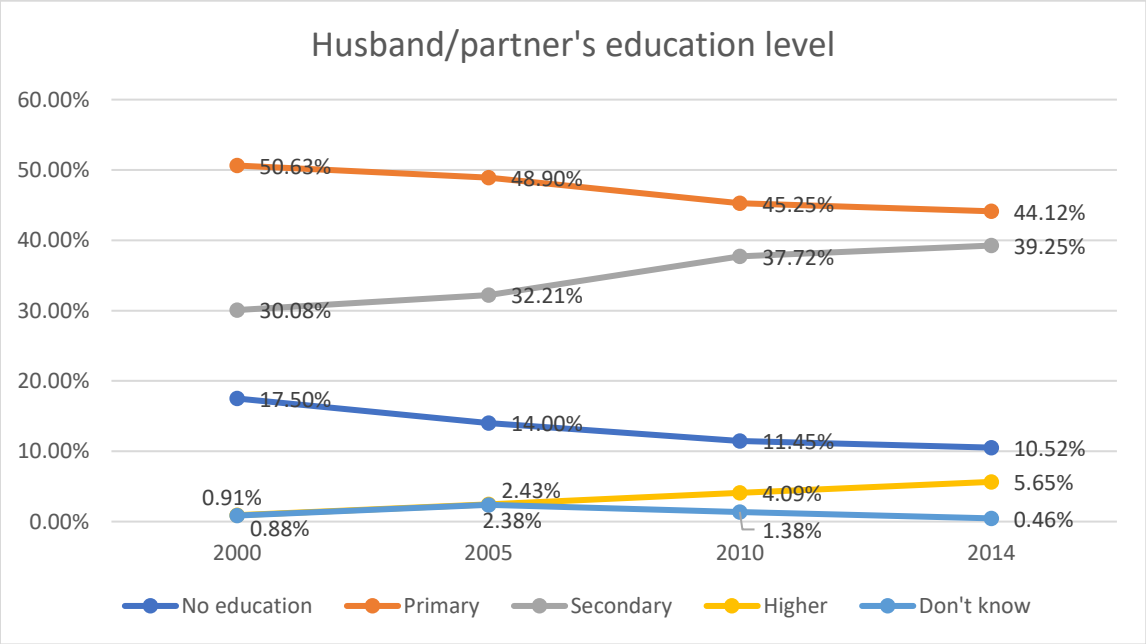
Appendices

Figure 1: Change of Parental Education Level From 2000-2014

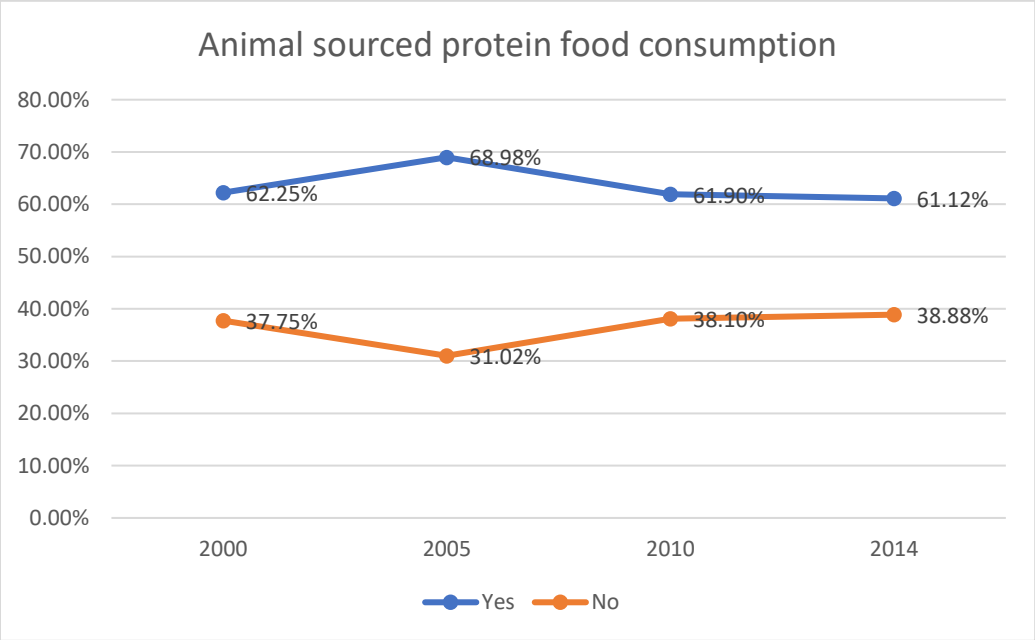


Note: 1) Survey adjusted 2) 2014 sample size N= 4,427; 2010 sample size N=3,888; 2005 sample size N=3,796; 2000 sample size N=.3,774 3) Source: National Institute of Statistics/Cambodia et al., 2015;2011;2006;2001

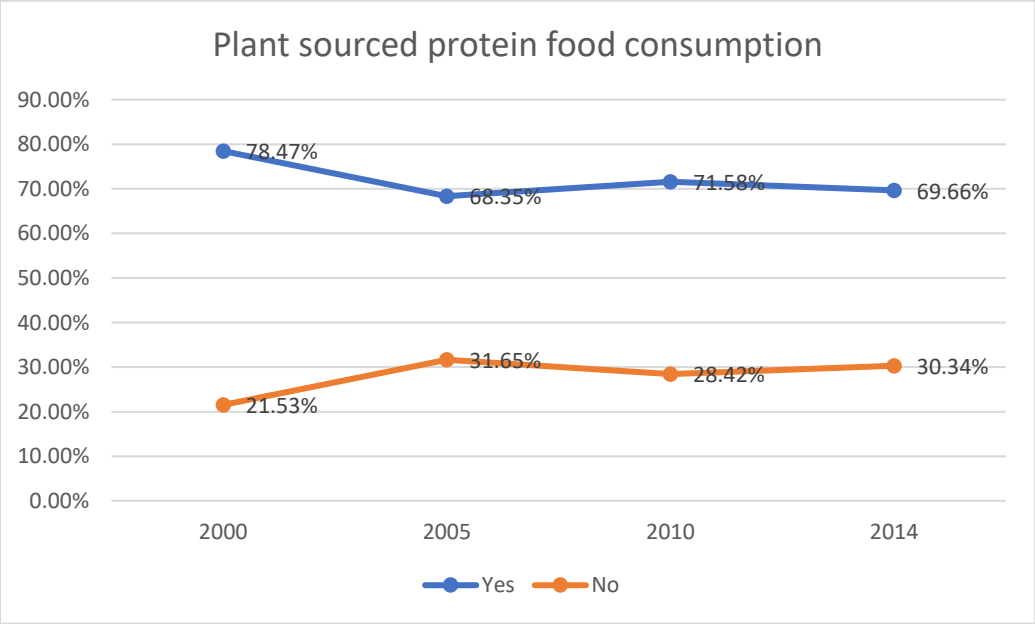


Note: 1) Survey adjusted 2) 2014 sample size N= 4,426; 2010 sample size N=3,828; 2005 sample size N=3,671; 2000 sample size N=.3,732 3) Source: National Institute of Statistics/Cambodia et al., 2015;2011;2006;2001

Figure 2: Protein Food Consumption From 2000-2014



Note: 1) Survey adjusted 2) Major sourced of animal protein include fresh milk (v412), egg (v414g), meat (v414h), fish (v414n), and milk products (v414p). 3) Major sourced of plant protein include foods from grains (v414e) and foods from beans, peas, lentils, and nuts (v414o). 4) 2014 sample size N= 2,426; 2010 sample size N=2,152; 2005 sample size N=2,928; 2000 sample size N= 3,701. 5) Source: National Institute of Statistics/Cambodia et al., 2015;2011;2006;2001



Note: 1) Survey adjusted 2) Major sourced of animal protein include fresh milk (v412), egg (v414g), meat (v414h), fish (v414n), and milk products (v414p). 3) Major sourced of plant protein include foods from grains (v414e) and foods from beans, peas, lentils, and nuts (v414o). 4) 2014 sample size N= 2,426; 2010 sample size N=2,152; 2005 sample size N=2,931; 2000 sample size N= 3,711. 5) Source: National Institute of Statistics/Cambodia et al., 2015;2011;2006;2001