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Food environment and child diet quality in Vietnam and Cambodia

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Food environment and child diet quality in Vietnam and Cambodia

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An abstract of
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Doctor Philosophy

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2022

ABSTRACT

Food environment and child diet quality in Vietnam and Cambodia

By Cam Duong

Objective: Ensuring a healthy, diverse diet in early life is critical to optimal nutrition during childhood and through the life course. However, most studies of child diet quality in resource-constrained settings are cross-sectional, which limit our understanding of dietary changes in the early childhood. Furthermore, few studies have used a food system approach to understand how food environment influences parental food choice and child diet quality. The objective of this dissertation is to characterize temporal dietary patterns in the early childhood and assess the linkage between food environment and child diet quality.

Methods: In Aim 1, we empirically constructed temporal patterns of minimum dietary diversity using prospectively collected data between 6 and 24 months in a birth cohort (n = 781) from rural Vietnam. The associations between the temporal dietary patterns and conditional growth outcomes measured during the same period were then evaluated. In Aim 2, we assessed whether better access to fresh food markets was associated with better dietary diversity in children aged 6 to 24 months in rural Cambodia by combining Cambodia Demographic and Health Survey data (n = 1594) with a national listing of fresh food markets (n = 485). In Aim 3, we carried out 24 in-depth interviews and 2 focus group discussions with mothers of preschool children across the rural-urban spectrum in Vietnam to understand children's eating patterns, mothers' perception of food environment and mothers' food choice behaviors.

Results: In Aim 1, we identified two key aspects of diet quality in early childhood, including the initiation of diverse diet and the stability of diverse diet over time. The optimal dietary pattern included children who started a diverse diet between 6 and 8 months and maintained this diet afterwards. However, less than a third of our sample followed this optimal diet and children deviating from the optimal diet experienced a slower growth in first two years of life. For example, compared to children with optimal dietary pattern, children who started diverse diet after their first birthday experienced 0.25 z-score lower gain in conditional HAZ (β: -0.25; 95% CI: -0.49, -0.02). In Aim 2, we found that longer distance to nearest fresh food markets was modestly associated with lower children's dietary diversity score (β: -0.16; 95% CI: -0.28, -0.05, but this association was non-significant among the low-income households. In Aim 3, we found that children's eating patterns indeed changed over time, which were likely to due to the seasonality of household food availability and the changes in child eating behaviors. We also found that most mothers expressed intentions to feed children nutritious fresh food for healthy growth, but some mothers face difficulties in securing sufficient food for families during lean season or in managing food refusal and fussiness in children.

Conclusions: Many children did not start diverse diet at the recommended time between 6 and 8 months or maintain the diverse diet afterwards. These children may experience slower linear growth and weight gain during the first 2 years of life. Possible reasons for delayed, unstable diverse diet are the poor accessibility to food markets, the seasonality of fresh food supply, the presence of packaged foods and beverages to replace nutritious fresh food, the lack of household resources for food acquisition and difficulties in managing child eating behaviors. Ensuring timely, stable diverse diet requires both behavioral change programs to improve caregivers' responsive feeding practices and policies to promote healthy, diverse and resilient food environment.

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Chapter 1: Introduction

Early childhood is a developmental stage critical for setting up healthy diet, eating behaviors and nutrition throughout the life course. In the first year of life, children make an important transition from breastmilk to family food that are increasingly rich in taste and texture (WHO, 2003, 2005). This is also a time of rapid growth, during which poor diet could increase the risk of infections and hamper linear growth or optimal weight gain (Millward, 2017). While deficits in weight can be regained with good diet afterwards, catch-up in linear growth after the first two years of life may be unlikely (Millward, 2017). The first two years of life is also a period when children obtain oral-motor skills and learn to communicate their hunger cues and food preferences, which influence parental food choice and feeding styles (Daniels, 2019). For these reasons, ensuring children eat well in their early years is challenging but important to a healthy childhood and adulthood.

In low-and-middle-income countries (LMIC), about 22% of the children were stunted (UNICEF et al., 2020) and 73% were given diet lacking nutrient-dense food such as egg, meat and fruits and vegetables (Gatica-Domínguez et al., 2021). These troubling statistics reflect the need for better understanding of young children's dietary patterns, caregivers' feeding practices and their socioecological drivers to develop effective interventions. While there has been a large number of research studies on young children's diet and feeding practices, two key gaps remain.

First, the relationship between diet quality and health outcomes is likely to reflect the accumulation of dietary exposure over times; thus, it is ideal to characterize diet using longitudinal studies to understand the dynamics of diet quality and the role of diet on health. However, most studies of diet quality in early life are cross-sectional, which limits our understanding of how young children eat throughout the critical period between 6 and 24 months. Furthermore, the evidence relating the cross-sectional measures of diet quality indicators and nutritional outcomes in LMIC is inconclusive, which prompts the need for more robust assessment of diet quality to support programs targeting at improving child diet (Jones et al., 2014). In high-income countries, the literature of child diet quality has moved towards characterizing temporal dietary patterns using

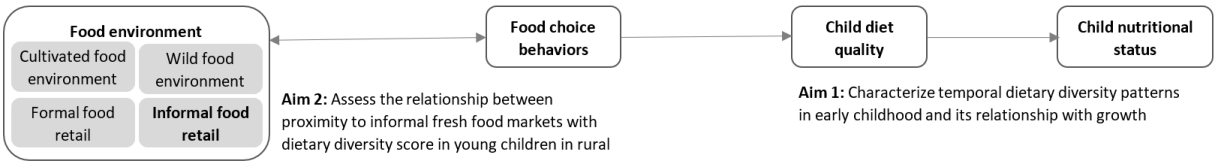
longitudinal studies and assessing how these patterns predict the risk of overweight and obesity (Brazionis et al., 2012; Lim et al., 2016; Manohar et al., 2021; Smithers et al., 2013). Characterizing temporal dietary patterns has the potential to gain deeper insights into different aspects of diet quality in the early life.

Second, existing studies of child diet quality have focused largely on the role of household and individual factors such as maternal knowledge, household wealth and household food distribution, and less is known about the role of the food environment. Global policy makers have recognized the importance of food environment, defined as the interface between larger food supply chain and individuals, and proposed a food system framework to better understand the drivers of diet (HLPE, 2017). Food environment can be categorized into four main typologies, including the wild food environment such as forests, jungles and natural lakes that provide wild harvest food, the cultivated food environment such as farms, pastures or gardens where food are grown, the informal market food environment such as wet markets and street vendors where food are sold by unlicensed vendors, and lastly the formal food environment such as supermarkets, retail stores and supermarkets where food are sold by licensed retailers (Downs et al., 2020). Food environment in LMICs is rapidly changing with the co-existence of several typologies such as industrial farming, small-sized farming, informal food retails and formal food retails. These changes have the potential to increase the availability of both nutrient-rich and nutrient-poor food but also inflate the price of fresh, nutritious food relative to nutrient-poor food such as cereals, sugar, sweets and fats. How these changes influence caregivers' decisions about food acquisitions and child feeding are not well understood and merit further research.

This dissertation aims to better understand the dynamics of diet quality in early life and how it is related to the food environment in Vietnam and Cambodia, two Southeast Asia countries undergoing socioeconomic and food environment transition. This research will adapt the food system framework to guide the development of research questions (Figure 1). Specifically, we first carried out a longitudinal analysis of a birth cohort in rural Vietnam to characterize the temporal patterns of dietary diversity and their relationships with growth outcomes (Aim 1) and subsequently a spatial analysis of the relationships between access to fresh, informal food markets and child dietary diversity in rural Cambodia (Aim 2). Finally, the quantitative evidence

generated from the first two aims will be verified and complemented by the qualitative study of maternal food choice for preschool children across the urban-rural areas in Vietnam (Aim 3), in which we explored children's eating patterns, mothers' perception of food environment, their food acquisition practices, and their decision-making surrounding food choice for children.

Figure 1: Conceptual framework of the socioecological drivers of diet and nutrition in early childhood



1.1 References

Brazionis, L., Golley, R. K., Mittinty, M. N., Smithers, L. G., Emmett, P., Northstone, K., & Lynch, J. W. (2012). Characterization of transition diets spanning infancy and toddlerhood: a novel, multiple-time-point application of principal components analysis. *The American Journal of Clinical Nutrition*, *95*(5), 1200-1208. https://doi.org/10.3945/ajcn.111.026575

Daniels, L. A. (2019). Feeding Practices and Parenting: A Pathway to Child Health and Family Happiness. *Annals of Nutrition and Metabolism*, *74(suppl 2)*(2), 29-42. https://doi.org/10.1159/000499145

Downs, S. M., Ahmed, S., Fanzo, J., & Herforth, A. (2020). Food Environment Typology: Advancing an Expanded Definition, Framework, and Methodological Approach for Improved Characterization of Wild, Cultivated, and Built Food Environments toward Sustainable Diets [Article]. *Foods*, *9*(4), 32, Article 532. https://doi.org/https://doi.org/10.3390/foods9040532

Gatica-Domínguez, G., Neves, P. A. R., Barros, A. J. D., & Victora, C. G. (2021). Complementary Feeding Practices in 80 Low- and Middle-Income Countries: Prevalence of and Socioeconomic Inequalities in Dietary Diversity, Meal Frequency, and Dietary Adequacy. *J Nutr*, *151*(7), 1956-1964. https://doi.org/10.1093/jn/nxab088

HLPE. (2017). *Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.*

Jones, A. D., Ickes, S. B., Smith, L. E., Mbuya, M. N., Chasekwa, B., Heidkamp, R. A., Menon, P., Zongrone, A. A., & Stoltzfus, R. J. (2014). World Health Organization infant and young child feeding indicators and their associations with child anthropometry: a synthesis of recent findings. *Matern Child Nutr*, *10*(1), 1-17. https://doi.org/10.1111/mcn.12070

Lim, G. H., Toh, J. Y., Aris, I. M., Chia, A.-R., Han, W. M., Saw, S. M., Godfrey, K. M., Gluckman, P. D., Chong, Y.-S., Yap, F., Lee, Y. S., Kramer, M. S., & Chong, M. F.-F. (2016). Dietary Pattern Trajectories from 6 to 12 Months of Age in a Multi-Ethnic Asian Cohort. *Nutrients*, *8*(6), 365. https://doi.org/10.3390/nu8060365

Manohar, N., Hayen, A., Do, L., Scott, J., Bhole, S., & Arora, A. (2021). Early life and socio-economic determinants of dietary trajectories in infancy and early childhood – results from the HSHK birth cohort study. *Nutrition Journal*, *20*(1), 76. https://doi.org/10.1186/s12937-021-00731-3

Millward, D. J. (2017). Nutrition, infection and stunting: the roles of deficiencies of individual nutrients and foods, and of inflammation, as determinants of reduced linear growth of children. *Nutrition Research Reviews*, *30*(1), 50-72. https://doi.org/https://doi.org/10.1017/s0954422416000238

Smithers, L. G., Golley, R. K., Mittinty, M. N., Brazionis, L., Northstone, K., Emmett, P., & Lynch, J. W. (2013). Do dietary trajectories between infancy and toddlerhood influence IQ in childhood and adolescence? Results from a prospective birth cohort study. *Plos One*, *8*(3), e58904-e58904. https://doi.org/10.1371/journal.pone.0058904

UNICEF, WHO, & World Bank Group. (2020). Joint Child Malnutrition Estimates.

WHO. (2003). *Guiding principles for feeding breastfed children 6-24 months of age.*

WHO. (2005). *Guiding principles for feeding non-breastfed children 6-24 months of age.*

Chapter 2: Background and literature review

A healthy, diverse diet in early life provides macro- and micro-nutrients needed to support immune system, bone lengthening and muscular growth (Millward, 2017), which creates the foundation for children to reach their optimal growth and healthy life during and after the childhood (Adair et al., 2013). In UNICEF conceptual framework of undernutrition, which was developed in 1990 and updated in 2020, diet quality is considered an immediate determinant of child nutrition and influenced by underlying drivers such as family feeding practices, family resources to acquire food, cultural norm, women's empowerment and governance (Figure 2) (UNICEF, 1990, 2020). Although this framework acknowledges the role of governance, which include broader macro-factors such as financial system, political system and private sector, it largely emphasizes the role of households and individuals on determining child nutrition. As a result, the majority of interventions targeting child nutrition in general or child diet quality in specific have focused on changing behaviors of caregivers, supporting homestead food production or providing cash transfer for families to acquire food.

Although these interventions have been showed to be effective (Manley et al., 2020; Margolies et al., 2022), the global statistics indicate that more than 70% of the children aged 6 to 23 months consume diet lacking key nutrient-rich food such as eggs, meat, fruits and vegetables. The unfinished agenda of child undernutrition, together with the concern of rising overweight and chronic diseases in LMIC, has prompted global policy makers to shift focus from individuals and households to food environment and food system (Figure 3) (HLPE, 2017). According to this framework, the wider system of food production, distribution, retailing and marketing shapes food environment, which is defined as the surrounding environment which individuals directly interact with to access and acquire food. The food environment, together with other factors such as individual demographics, socio-cultural drivers and economic drivers, determines individuals' food choice decision-making and behaviors, which subsequently affect their diet and nutritional outcomes. Although this framework was not designed specifically to addressing child nutrition, it is valuable to shift the focus from household and individuals to food system actors. One such actor is informal food retailers, who

are traders or farmers selling their home-grown produce. They play a crucial role in the rural-urban food linkages while supporting rural economies that are transitioning to non-farm activities. Most informal retailers of fresh produce are organized into informal food markets while few are itinerant vendors who move from place to place. According to a review of food system typologies (Figure 4), informal food system and informal food markets plays an important role in the food system in many low-and-middle-income countries that experience transition in socioeconomics, agricultural production and urban development (Downs et al., 2020).

Our work contributes to the literature of child nutrition by focusing on the linkage between food environment, food choice behaviors and child diet quality. This chapter provides relevant background on different forms of child malnutrition, the global situation of child diet quality, the determinants of caregivers' food choice behaviors and lastly the conceptualization of food environment. This chapter will be concluded by a summary of current literature and key gaps.

Figure 2: UNICEF Conceptual framework on the determinants of maternal and child nutrition

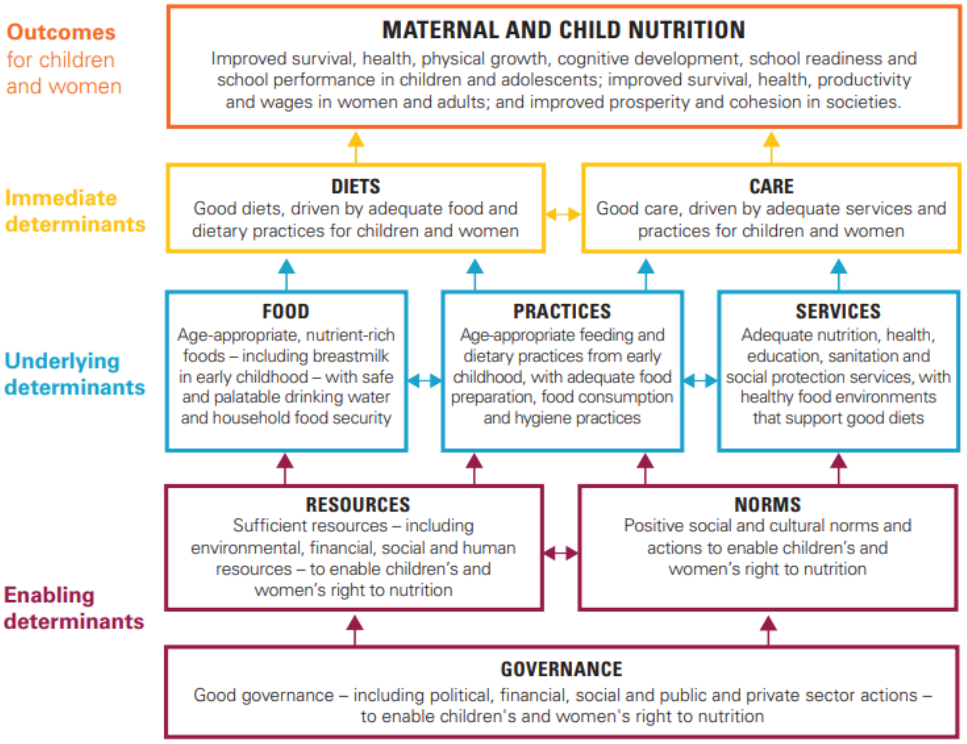


Figure 3: Conceptual framework of food systems for diets and nutrition

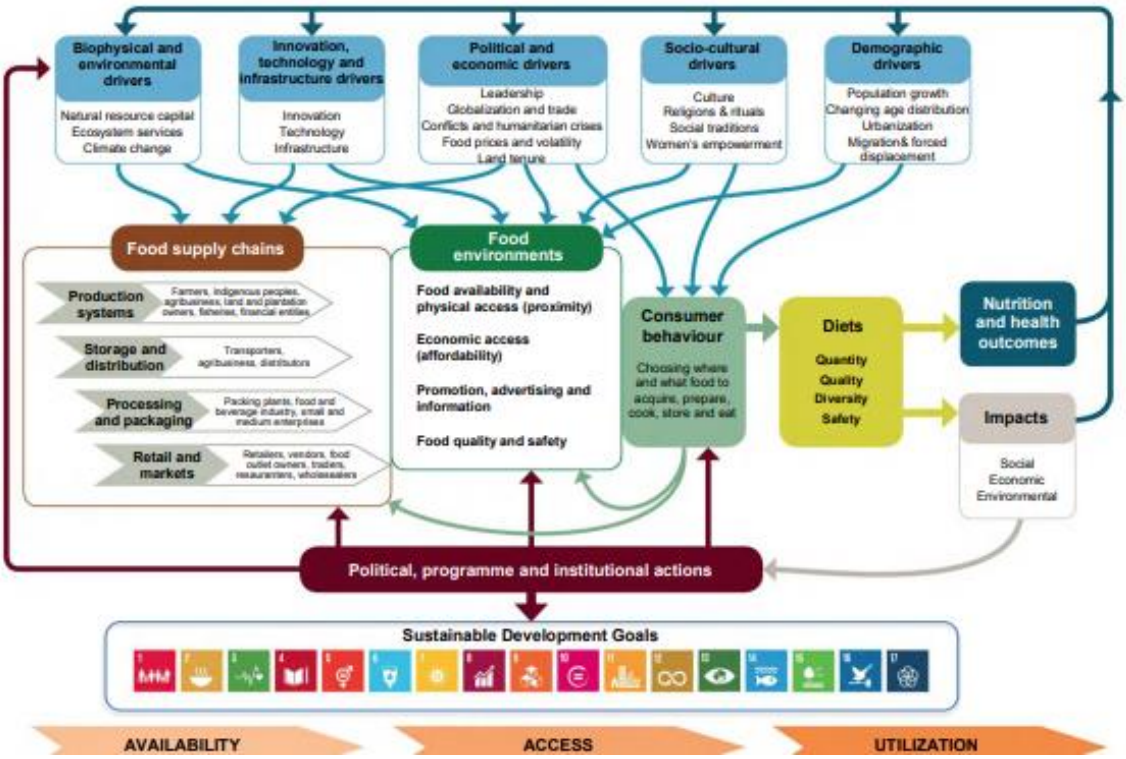


Figure 4: Food environment typologies

2.1 Child nutrition

Undernutrition during early life remains a persistent challenge in LMIC (Victora et al., 2021). According to World Health Organization (WHO), three major forms of undernutrition include underweight, wasting and

stunting, which are defined as having weight-for-age z-score, weight-for-height z-score and height-for-age z-score, respectively, two standard deviation below the WHO Child Growth Standards (World Health Organization, 2016). Common to these three forms of undernutrition is the deficiency in micronutrients essential for growth and development such as vitamin A, vitamin D, iron and zinc. Between 2000 and 2020, the global prevalence of stunting among children under five years of age has declined from 33.1% to 22% (UNICEF et al., 2020) while the prevalence of underweight shrunk from 20% to 12% (Global Nutrition Report, 2020). The prevalence of wasting was about 6.7% in 2022. However, these global statistics mask the heterogeneity between countries. Vietnam has undergone a significant economic growth, which contributed to the reduction of child stunting from 43% to 23% between 2000 and 2020 (Global Nutrition Report, 2020). During the 35th session of the Standing Committee in Nutrition, Vietnam was recognized as one of the few countries in Southeast Asia with reduction in child malnutrition close to the Millennium Development Goals (Ministry of Health & National Institute of Statistics, 2012). In contrast, Cambodia lagged behind with the stunting prevalence declining from 49% to 32% between 2000 and 2020 (Global Nutrition Report, 2020), which places Cambodia among the countries with highest stunting prevalence in Southeast Asia. The pattern of wasting looked slightly different with the wasting prevalence fluctuating around 6% in Vietnam and declining from 17% to 9% between 2000 and 2020 period in Cambodia (Global Nutrition Report, 2020).

The physiology of underweight, wasting and stunting differ in several ways. Both underweight and wasting are considered acute undernutrition and may reflect the body's response to episodes of hunger or infections. It is characterized by the rapid depletion of the fat stores and break down of muscle mass to maintain essential metabolic processes. While children who are wasted have a higher risk of subsequent wasting, wasting and underweight can generally be treated using ready-to-use therapeutic food (Emergency Nutrition Network, 2018). In contrast, stunting is considered long-term undernutrition and not reversible after two years of age. Stunting is the result of the accumulation of poor maternal and child undernutrition during the first 1000 days, a period including the preconception, pregnancy and the first two years of life (de Onis & Branca, 2016). While macronutrients such as proteins, carbohydrate and fat supply calories needed to prevent wasting and underweight, both macro- and micro-nutrients interact and influence linear growth (Millward,

2017). For example, amino acids, iodine, vitamin D and zinc participate in essential anabolic pathways, which involve the activation of endocrine and paracrine signaling to support bone lengthening and muscular growth. On the other hand, vitamin A and zinc play critical role in strengthening the immune system to prevent diarrhea and infections, the risk factors of stunted growth. While it is not fully understood how each individual macro- and micro-nutrient influence linear growth at different phase of early childhood, the synergistic and holistic actions of nutrients on linear growth signaling imply that a whole diet that are balanced in macronutrients and diverse in micronutrients are essential for growth.

Of the three forms of undernutrition, stunting has been the major target of child nutrition programs. After two years of age, deficits in height are unlikely to be regained through better diet or care and height at this age is a strong predictor of nutritional, educational and health outcomes in the adulthood (Adair et al., 2013; He & Stein, 2021). Prevention of stunting is the basis for investment in the nutrition during the first 1000 days of life (Food and Nutrition Technical Assistance III Project (FANTA), 2018) and takes root in the fetal origin hypothesis by David Barker and colleagues (Barker, 2012). Slower linear growth in the first two years of age has been linked to shorter adult stature, failure to complete secondary school, lower blood pressure, lower lean mass and higher fat mass ((Adair et al., 2013; De Lucia Rolfe et al., 2018). After two years of age, gaining too much weight too fast can increase the risk of overweight and chronic diseases (De Sanctis et al., 2021). One hypothesis accounting for these observations is that weight accumulated during the first two years of life is associated with the construction of lean mass needed for linear growth while weight gained after this period is associated with the accumulation of fat mass (Adair et al., 2013). Besides growth and health, linear growth in the first two years also better predicts intelligence than growth in older children and adolescents, possibly because rapid brain development also occurs in the first two years (De Sanctis et al., 2021).

The period between 6 to 23 months represents a key window to prevent growth faltering, wasting and underweight. In this period, children have to make an important transition from breastmilk or formula milk to food with increasing level of consistency, texture and flavors, a process defined as "complementary feeding". After 6 months, breastmilk alone is no longer sufficient to meet infants' nutritional needs and therefore other foods and liquids are also required. According to WHO Guidelines on complementary

feeding for breastfed and non-breastfed infants, complementary food should be safely prepared and stored, has the appropriate consistency and contain diverse food to provide sufficient nutrients for growth (WHO, 2003, 2005).

2.2 Child diet diversity

Dietary diversity score, or the number of food groups consumed out of a set of pre-defined food groups, is considered the cornerstone of child diet quality in early life. Higher dietary diversity score has been showed to correlate with higher intake of energy and micronutrients in several LMIC (Kennedy et al., 2007; Steyn et al., 2006). Dietary diversity is a core indicator developed in 2007 by the WHO to monitor infant and young child feeding in LMIC (WHO et al., 2008). According to this guideline, minimum dietary diversity was set at 4 out of 7 food groups. This indicator was then revised in 2017 by adding breastmilk to the count of nutrient-rich food and increasing the threshold to five food groups, the former was justified on the basis that breastmilk is recommended till two years of age (UNICEF & WHO, 2021; UNICEF et al., 2017). In analyses of data from South Asia and Eastern and Southern Africa regions, such revision led to the decrease in the prevalence of children who met minimum dietary diversity recommendation, suggesting that efforts to track and improve dietary diversity need to take caution not to mix the two definitions in their measure and interpretation (Heidkamp et al., 2020; Roy et al., 2022). According to the revised guideline, just about one-fourth of young children in LMIC met this recommendation (Gatica-Domínguez et al., 2021).

Since its development, dietary diversity score has been used widely to advocate for better diet in early childhood and measure program impact. However, findings are mixed about the strength of the associations of dietary diversity score with health and growth outcomes (Busert et al., 2016; Jones et al., 2014). A longitudinal study in Bangladesh showed that better dietary diversity score was not correlated with larger gain in linear growth in the period before two years of age (Busert et al., 2016). A systematic review of cross-sectional analyses also found mixed findings whereby minimum dietary diversity positively associating with height-for-age z-score in Bangladesh, India and Zambia but not in Ethiopia, Kenya and Haiti (Jones et al., 2014). These mixed findings may be explained by the low specificity of the minimum dietary diversity score

(i.e., the indicator correctly classifies children with inadequate diet as inadequate, but often misclassify children with adequate diet as inadequate), despite the strong correlation between dietary diversity score and mean micronutrient density adequacy (Jones et al., 2014). With low specificity, the minimum dietary diversity score is well suited to identify population at risk and in need of interventions, but it is not robust for program evaluation and for assessing causal link between diet and health (Jones et al., 2014).

One approach to identify stronger proxies of diet quality is to capture diet longitudinally. Characterizing diet longitudinally has been recommended as a strategy to better capture the relationship between diet and health (Reedy et al., 2018). Several longitudinal studies in European countries have identified several temporal dietary patterns, including a baby food pattern comprising of soft food such as pudding and cereals, a discretionary pattern that includes unhealthy food like chocolate, biscuits and sweets and a healthy pattern that includes diverse fresh food (Brazionis et al., 2012; Lim et al., 2016; Manohar et al., 2021; Smithers et al., 2013). These patterns have been showed to be associated with risks of overweight and obesity in the later childhood (Group, 2015; Liberali et al., 2020; Min et al., 2021). Similar approach can be adapted to LMIC setting to better understand the changes in dietary diversity over time and identify a stronger proxy of diet quality.

2.3 Parental food choice behaviors

Parents are main gatekeepers of child diet. Their food choice behaviors, here defined as behaviors surrounding what and how to feed their children, directly influence their children's diet quality, growth and health outcomes. However, many parents do not adopt optimal food choice behaviors. As for "*what to feed*", WHO guidelines recommends food of the right thickness with rich, diverse nutrients, but there are practices of feeding children dilute cereal gruels made primarily from grains and delaying giving children meat, eggs and fruits and vegetables (Dickin et al., 2021). As for "*how to fed*", the guideline advocates for responsive feeding, or feeding children with positive interaction and encouragement, but parents commonly follow children's preferences, such as not encouraging children to eat if they lack appetite or placating them with packaged snacks (Dickin et al., 2021).

The discrepancies between guidelines and real-world practices have prompted efforts to improve parental feeding practices, but overall success had been modest. Compared to the widespread promotion of exclusive breastfeeding, the success of complementary feeding practices is lagged behind (Baker et al., 2013; Piwoz et al., 2003). One reason is the complexity in dimensions of complementary feeding practices, such as the nutrient density and consistency of food and the way food is fed to children. The other reason is the complexity in the determinants and drivers of parental feeding practices. Conventionally, parental feeding practices are influenced by two main factors, including socio-cultural norms and household resources (UNICEF, 2020).

Parental decisions and practices surrounding child feeding is strongly rooted in culture and tradition. For example, animal-sourced food such as egg and flesh meat were not given to children in some nomadic cultures in Kenya that place prestige on the ownership of livestock, or in some religions in Ethiopia and Uganda that practice fasting or dietary restriction. In Laos, rice and chilies were viewed as supporting physical development while in Nigeria, "light" food rather than "heavy" food was thought to interfere with motor development in children (Dickin et al., 2021). Attempts to shift social norms in child feeding have been carried out intensively through a number of programs such as Spring in Niger, USAID Nourish in Cambodia and Alive and Thrive in Vietnam, Bangladesh and Ethiopia. These attempts include traditional behavioral change communication (BCC) activities such as individual counseling and engagement of religious leaders, but also new approaches such as media outreach and social franchising (Dickin et al., 2021). Lessons learned from these programs indicated that scaling up interventions to improve parental feeding practices is possible if adequate attentions and resources are given to program implementation, such as identifying the right local partners, incentivizing field workers and strengthening infrastructure and logistics of franchise centers (Baker et al., 2013).

While shifting socio-cultural norms can help create household and community demand for optimal feeding practices, improving economic status is crucial to ensuring a supply of adequate, diverse food for children. This rationale explains the branch of economic-focused interventions, including cash-transfer programs to directly provide households with cash or nutrition-sensitive agriculture programs to improve household food

availability through biofortification, development of husbandry or support for home gardens. A recent meta-analysis found that cash transfers have significant effects on the consumption of animal-source foods and dietary diversity (Manley et al., 2020). Nutrition-sensitive agriculture programs have also been showed to be effective in complementary feeding practices, largely through increase in food available in the household, reduced food prices and increased women empowerment associated with better income controlled by women (Sharma et al., 2021). While these programs have been successful in improving feeding practices, their effects on ultimate child nutritional outcomes such as stunting and wasting were mixed. These effects may depend on the program characteristics such as program duration, program intensity and the conditionality of the cash transfer or study context such as the baseline nutritional status, agroecology and seasonality (Manley et al., 2020; Sharma et al., 2021).

Although not discussed in the UNICEF framework, child eating behaviors also play an important role in determining child diet. Child eating behaviors and parental feeding practices influence each other and shape the early eating environment for children to grow and thrive. Studies of early child development has indicated infants' predispositions to sweet tastes, rejection of bitter or sour tastes and refusal of unfamiliar foods (Daniels, 2019). These early preferences continue to evolve together with the maturation of motor skills and development of temperament and autonomy. These normal development traits can manifest into behaviors such as picky or lazy eating, which influence parental feeding choices (Daniels, 2019). For this reason, WHO guidelines on complementary feeding recommend parents and caregivers practicing responsive feeding. This practice applies the principles of pscyho-social care and recognizes that feeding times are periods of learning and loving. It encourages parents and caregivers to feed children patiently, experiment with different combination of foods, tastes and textures to increase food acceptance, and use verbal encouragement and eye-to-eye contact without forcing children to eat (WHO, 2003, 2005). Thus far, a few programs have attempted to incorporate responsive feeding in their behavioral change programs to improve overall child feeding such as the Baduta program in Indonesia and Nourish program in Cambodia (Dougherty et al., 2016; Magarey et al., 2016). These programs have reported positive results on maternal knowledge of responsive feeding practices and reported child food acceptance behaviors. However, a systematic review reported null

associations between responsive feeding and child growth outcomes, possibly because the discrepancies between self-reported and actual practices (Bentley et al., 2011).

2.4 Food environment

According to the food system framework (Figure 2), food environment directly influences consumers' food choice behaviors. Food environment concept was first built upon socioecological model to understand the determinants of obesity and chronic diseases in high-income countries. Pioneered by Glanz et al. (2007), food environment is defined at the community scale and in-store scale. This conceptualization distinguished between individual and household factors with the physical world outside household, which generated early evidence on the link between food environment and overnutrition outcomes. Afterwards, Swinburn et al. (2013) defined the food environment as the "collective physical, economic, policy and sociocultural surroundings, opportunities and conditions that influence people's food and beverage choices and nutritional status" and subsequently Herforth and Ahmed (2015) pinpointed the various dimensions of food environment to include "availability, affordability, convenience and desirability". As nutrition research in LMIC increasingly recognizes the role of food system and look beyond individual and household contribution to health, food environment research has also been considered a new target for programs and interventions, as emphasized by the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2017, 2020).

Evolving in parallel with food environment research is the research on the role of access to rural food markets in child nutrition, which was motivated by the observation that most smallholder farm households are not strictly subsistence-oriented and by the need to weight the benefits of selling cash crops to generate income to purchase food against the benefits of growing diverse food for home consumption. Rural food markets are indeed key characteristics of the food environment and food system in LMIC. Its role is prominent especially in settings where households are shifting from growing food crops to cash crops and from farm to non-farm activities (Haggblade et al., 2010). Even among subsistence farmers, such as those in Ethiopia and Malawi, over half of the food consumed at home was acquired from markets (Sibhatu et al.,

2015). Better access to markets has been proposed to improve household food access and child nutrition through reducing time and cost of food acquisition and increasing household purchasing power via opportunities to acquire modern agricultural inputs and trade goods at the markets (Nandi et al., 2021). Many empirical studies have showed a consistent association of food market access with better dietary diversity in households and women with more limited evidence regarding children (Headey et al., 2019; Hirvonen et al., 2017; Luckett et al., 2015; Nandi et al., 2021; Sibhatu et al., 2015; Stifel & Minten, 2017). In addition, some studies suggested that the effects of better access to market and better child dietary diversity are modified by other factors such as maternal nutritional knowledge or seasonality.

2.5 Knowledge gaps

The first two years of age is the period when children see rapid growth failure. While several aspects of early life diet such as exclusive breastfeeding or timely initiation of solid food have improved significantly, ensuring a diverse diet remains a major challenge with less than 30% of the children globally meeting the minimum diverse diet recommendation of five food groups. Policies and programs targeting food environment may be needed to address this challenge. Furthermore, cross-sectional dietary diversity measures are not robust to predict growth outcomes and limited in providing insights into the variability of diet over time. Programs that aim to improve young children diet need better insights into the dynamics of diverse diet over time and the linkage between food environment and diet.

Based on these knowledge gaps, this dissertation aims to employ food system framework to characterize the dietary diversity changes during the early childhood and assess the linkage between food environment and dietary diversity in rural areas in Vietnam and Cambodia. A mixed-method approach that combines spatial, longitudinal and qualitative data in Vietnam and Cambodia will be used to accomplish this aim.

2.6 References

Adair, L. S., Fall, C. H. D., Osmond, C., Stein, A. D., Martorell, R., Ramirez-Zea, M., Sachdev, H. S., Dahly, D. L., Bas, I., Norris, S. A., Micklesfield, L., Hallal, P., & Victora, C. G. (2013). Associations of linear

growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: findings from five birth cohort studies. *The Lancet*, *382*(9891), 525-534. https://doi.org/https://doi.org/10.1016/S0140-6736(13)60103-8

Baker, J., Sanghvi, T., Hajeebhoy, N., & Abrha, T. H. (2013). Learning from the design and implementation of large-scale programs to improve infant and young child feeding. *Food Nutr Bull*, *34*(3 Suppl), S226-230. https://doi.org/10.1177/15648265130343s208

Barker, D. J. P. (2012). Sir Richard Doll Lecture. Developmental origins of chronic disease. *Public Health*, *126*(3), 185-189. https://doi.org/10.1016/j.puhe.2011.11.014

Bentley, M. E., Wasser, H. M., & Creed-Kanashiro, H. M. (2011). Responsive Feeding and Child Undernutrition in Low- and Middle-Income Countries. *The Journal of Nutrition*, *141*(3), 502-507. https://doi.org/10.3945/jn.110.130005

Brazionis, L., Golley, R. K., Mittinty, M. N., Smithers, L. G., Emmett, P., Northstone, K., & Lynch, J. W. (2012). Characterization of transition diets spanning infancy and toddlerhood: a novel, multiple-time-point application of principal components analysis. *The American Journal of Clinical Nutrition*, *95*(5), 1200-1208. https://doi.org/10.3945/ajcn.111.026575

Busert, L. K., Neuman, M., Rehfuess, E. A., Dulal, S., Harthan, J., Chaube, S. S., Bhandari, B., Costello, H., Costello, A., Manandhar, D. S., & Saville, N. M. (2016). Dietary Diversity Is Positively Associated with Deviation from Expected Height in Rural Nepal. *The Journal of Nutrition*, *146*(7), 1387-1393. https://doi.org/10.3945/jn.115.220137

Daniels, L. A. (2019). Feeding Practices and Parenting: A Pathway to Child Health and Family Happiness. *Annals of Nutrition and Metabolism*, *74(suppl 2)*(2), 29-42. https://doi.org/10.1159/000499145

De Lucia Rolfe, E., de França, G. V. A., Vianna, C. A., Gigante, D. P., Miranda, J. J., Yudkin, J. S., Horta, B. L., & Ong, K. K. (2018). Associations of stunting in early childhood with cardiometabolic risk factors in adulthood. *Plos One*, *13*(4), e0192196. https://doi.org/10.1371/journal.pone.0192196

de Onis, M., & Branca, F. (2016). Childhood stunting: a global perspective. *Maternal & Child Nutrition*, *12 Suppl 1*(Suppl 1), 12-26. https://doi.org/10.1111/mcn.12231

De Sanctis, V., Soliman, A., Alaaraj, N., Ahmed, S., Alyafei, F., & Hamed, N. (2021). Early and Long-term Consequences of Nutritional Stunting: From Childhood to Adulthood. *Acta Biomed*, *92*(1), e2021168. https://doi.org/10.23750/abm.v92i1.11346

Dickin, K. L., Litvin, K., McCann, J. K., & Coleman, F. M. (2021). Exploring the Influence of Social Norms on Complementary Feeding: A Scoping Review of Observational, Intervention, and Effectiveness Studies. *Current developments in nutrition*, *5*(2). https://doi.org/https://doi.org/10.1093/cdn/nzab001

Dougherty, L., Marjolein, M., Chaibou, D., & Sophie, M. (2016). *Seeing Is Believing: Evidence from a Community Video Approach for Nutrition and Hygiene Behaviors* (Strengthening Partnerships, Results, and Innovations in Nutrition Globally (SPRING) project, Issue.

Downs, S. M., Ahmed, S., Fanzo, J., & Herforth, A. (2020). Food Environment Typology: Advancing an Expanded Definition, Framework, and Methodological Approach for Improved Characterization of Wild, Cultivated, and Built Food Environments toward Sustainable Diets [Article]. *Foods*, *9*(4), 32, Article 532. https://doi.org/https://doi.org/10.3390/foods9040532

Emergency Nutrition Network. (2018). *The aetiology of wasting*.

Food and Nutrition Technical Assistance III Project (FANTA). (2018). *Strengthening the evidence base for nutrition interventions during the "1000 days": FANTA research explores how to optimize the prevention of malnutrition*.

Gatica-Domínguez, G., Neves, P. A. R., Barros, A. J. D., & Victora, C. G. (2021). Complementary Feeding Practices in 80 Low- and Middle-Income Countries: Prevalence of and Socioeconomic Inequalities in Dietary Diversity, Meal Frequency, and Dietary Adequacy. *J Nutr*, *151*(7), 1956-1964. https://doi.org/10.1093/jn/nxab088

Glanz, K., Sallis, J. F., Saelens, B. E., & Frank, L. D. (2007). Nutrition Environment Measures Survey in Stores (NEMS-S): Development and Evaluation. *American Journal of Preventive Medicine*, *32*(4), 282-289. https://doi.org/https://doi.org/10.1016/j.amepre.2006.12.019

Global Nutrition Report. (2020). *Country Nutrition Profiles*. Retrieved December from https://globalnutritionreport.org/resources/nutrition-profiles/

Group, E. M. C. C. S. (2015). Dietary Patterns Track from Infancy to Preschool Age: Cross-Sectional and Longitudinal Perspectives. *The Journal of Nutrition*, *145*(4), 775-782. https://doi.org/10.3945/jn.114.201988

Haggblade, S., Hazell, P., & Reardon, T. (2010). The Rural Non-farm Economy: Prospects for Growth and Poverty Reduction. *World Development*, *38*(10), 1429-1441. https://doi.org/https://doi.org/10.1016/j.worlddev.2009.06.008

He, S., & Stein, A. D. (2021). Early-Life Nutrition Interventions and Associated Long-Term Cardiometabolic Outcomes: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Adv Nutr*, *12*(2), 461-489. https://doi.org/10.1093/advances/nmaa107

Headey, D., Hirvonen, K., Hoddinott, J., & Stifel, D. (2019). Rural Food Markets and Child Nutrition. *American Journal of Agricultural Economics*, *101*, 1311-1327. https://doi.org/https://doi.org/10.1093/ajae/aaz032

Heidkamp, R. A., Kang, Y., Chimanya, K., Garg, A., Matji, J., Nyawo, M., Craig, H., Arimond, M., & Lyman, A. L. T. (2020). Implications of Updating the Minimum Dietary Diversity for Children Indicator for Tracking Progress in the Eastern and Southern Africa Region. *Current developments in nutrition*, *4*(9), nzaa141. https://doi.org/10.1093/cdn/nzaa141

Herforth, A., & Ahmed, S. (2015). The food environment, its effects on dietary consumption, and potential for measurement within agriculture-nutrition interventions. *Food Security*, *7*(3), 505-520. https://doi.org/10.1007/s12571-015-0455-8

Hirvonen, K., Hoddinott, J., Minten, B., & Stifel, D. (2017). Children's Diets, Nutrition Knowledge, and Access to Markets. *World Development*, *95*, 303-315. https://doi.org/https://doi.org/10.1016/j.worlddev.2017.02.031

HLPE. (2017). *Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.*

HLPE. (2020). *Food security and nutrition: Building a global narrative towards 2030* (A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Issue.

Jones, A. D., Ickes, S. B., Smith, L. E., Mbuya, M. N., Chasekwa, B., Heidkamp, R. A., Menon, P., Zongrone, A. A., & Stoltzfus, R. J. (2014). World Health Organization infant and young child feeding indicators and their associations with child anthropometry: a synthesis of recent findings. *Matern Child Nutr*, *10*(1), 1-17. https://doi.org/10.1111/mcn.12070

Kennedy, G. L., Pedro, M. R., Seghieri, C., Nantel, G., & Brouwer, I. (2007). Dietary Diversity Score Is a Useful Indicator of Micronutrient Intake in Non-Breast-Feeding Filipino Children. *The Journal of Nutrition*, *137*(2), 472-477. https://doi.org/10.1093/jn/137.2.472

Liberali, R., Kupek, E., & Assis, M. A. A. (2020). Dietary Patterns and Childhood Obesity Risk: A Systematic Review. *Child Obes*, *16*(2), 70-85. https://doi.org/10.1089/chi.2019.0059

Lim, G. H., Toh, J. Y., Aris, I. M., Chia, A.-R., Han, W. M., Saw, S. M., Godfrey, K. M., Gluckman, P. D., Chong, Y.-S., Yap, F., Lee, Y. S., Kramer, M. S., & Chong, M. F.-F. (2016). Dietary Pattern Trajectories from 6 to 12 Months of Age in a Multi-Ethnic Asian Cohort. *Nutrients*, *8*(6), 365. https://doi.org/10.3390/nu8060365

Luckett, B. G., DeClerck, F. A. J., Fanzo, J., Mundorf, A. R., & Rose, D. (2015). Application of the Nutrition Functional Diversity indicator to assess food system contributions to dietary diversity and sustainable diets of Malawian households. *Public Health Nutrition*, *18*(13), 2479-2487. https://doi.org/https://doi.org/10.1017/S136898001500169X

Magarey, A., Mauch, C., Mallan, K., Perry, R., Elovaris, R., Meedeniya, J., Byrne, R., & Daniels, L. (2016). Child dietary and eating behavior outcomes up to 3.5 years after an early feeding intervention: The NOURISH RCT. *Obesity (Silver Spring)*, *24*(7), 1537-1545. https://doi.org/10.1002/oby.21498

Manley, J., Balarajan, Y., Malm, S., Harman, L., Owens, J., Murthy, S., Stewart, D., Winder-Rossi, N. E., & Khurshid, A. (2020). Cash transfers and child nutritional outcomes: a systematic review and meta-analysis. *BMJ Global Health*, *5*(12), e003621. https://doi.org/https://doi.org/10.1136/bmjgh-2020-003621

Manohar, N., Hayen, A., Do, L., Scott, J., Bhole, S., & Arora, A. (2021). Early life and socio-economic determinants of dietary trajectories in infancy and early childhood – results from the HSHK birth cohort study. *Nutrition Journal*, *20*(1), 76. https://doi.org/10.1186/s12937-021-00731-3

Margolies, A., Kemp, C. G., Choo, E. M., Levin, C., Olney, D., Kumar, N., Go, A., Alderman, H., & Gelli, A. (2022). Nutrition-sensitive agriculture programs increase dietary diversity in children under 5 years: A review and meta-analysis. *J Glob Health*, *12*, 08001. https://doi.org/10.7189/jogh.12.08001

Millward, D. J. (2017). Nutrition, infection and stunting: the roles of deficiencies of individual nutrients and foods, and of inflammation, as determinants of reduced linear growth of children. *Nutrition Research Reviews*, *30*(1), 50-72. https://doi.org/https://doi.org/10.1017/s0954422416000238

Min, K., Wang, J., Liao, W., Astell-Burt, T., Feng, X., Cai, S., Liu, Y., Zhang, P., Su, F., Yang, K., Sun, L., Zhang, J., Wang, L., Liu, Z., & Jiang, Y. (2021). Dietary patterns and their associations with overweight/obesity among preschool children in Dongcheng District of Beijing: a cross-sectional study. *Bmc Public Health*, *21*(1), 223. https://doi.org/10.1186/s12889-021-10240-x

Ministry of Health, & National Institute of Statistics. (2012). *National Nutrition Strategy for 2011–2020, with a Vision Towards 2030*. M. P. House.

Nandi, R., Nedumaran, S., & Ravula, P. (2021). The interplay between food market access and farm household dietary diversity in low and middle income countries: A systematic review of literature. *Global Food Security*, *28*, 100484. https://doi.org/https://doi.org/10.1016/j.gfs.2020.100484

Piwoz, E. G., Huffman, S. L., & Quinn, V. J. (2003). Promotion and advocacy for improved complementary feeding: can we apply the lessons learned from breastfeeding? *Food Nutr Bull*, *24*(1), 29-44. https://doi.org/10.1177/156482650302400103

Reedy, J., Subar, A. F., George, S. M., & Krebs-Smith, S. M. (2018). Extending Methods in Dietary Patterns Research. *Nutrients*, *10*(5). https://doi.org/10.3390/nu10050571

Roy, A., Hossain, M. M., Hanif, A. A. M., Khan, M. S. A., Hasan, M., Hossaine, M., Shamim, A. A., Ullah, M. A., Sarkar, S. K., Rahman, S. M. M., Bulbul, M. M. I., Mitra, D. K., & Mridha, M. K. (2022). Prevalence of Infant and Young Child Feeding Practices and Differences in Estimates of Minimum

Dietary Diversity Using 2008 and 2021 Definitions: Evidence from Bangladesh. *Curr Dev Nutr*, *6*(4), nzac026. https://doi.org/10.1093/cdn/nzac026

Sharma, I. K., Di Prima, S., Essink, D., & Broerse, J. E. W. (2021). Nutrition-Sensitive Agriculture: A Systematic Review of Impact Pathways to Nutrition Outcomes. *Adv Nutr*, *12*(1), 251-275. https://doi.org/10.1093/advances/nmaa103

Sibhatu, K. T., Krishna, V. V., & Qaim, M. (2015). Production diversity and dietary diversity in smallholder farm households. *Proceedings of the National Academy of Sciences*, *112*(34), 10657-10662. https://doi.org/https://doi.org/10.1073/pnas.1510982112

Smithers, L. G., Golley, R. K., Mittinty, M. N., Brazionis, L., Northstone, K., Emmett, P., & Lynch, J. W. (2013). Do dietary trajectories between infancy and toddlerhood influence IQ in childhood and adolescence? Results from a prospective birth cohort study. *Plos One*, *8*(3), e58904-e58904. https://doi.org/10.1371/journal.pone.0058904

Steyn, N. P., Nel, J. H., Nantel, G., Kennedy, G., & Labadarios, D. (2006). Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Nutr*, *9*(5), 644-650. https://doi.org/10.1079/phn2005912

Stifel, D., & Minten, B. (2017). Market Access, Well-being, and Nutrition: Evidence from Ethiopia. *World Development*, *90*, 229-241. https://doi.org/http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129406

Swinburn, B., Sacks, G., Vandevijvere, S., Kumanyika, S., Lobstein, T., Neal, B., Barquera, S., Friel, S., Hawkes, C., Kelly, B., L'Abbé, M., Lee, A., Ma, J., Macmullan, J., Mohan, S., Monteiro, C., Rayner, M., Sanders, D., Snowdon, W., . . . Informas. (2013). INFORMAS (International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support): overview and key principles [https://doi.org/10.1111/obr.12087]. *Obesity Reviews*, *14*(S1), 1-12. https://doi.org/https://doi.org/10.1111/obr.12087

UNICEF. (1990). *Improving Child Nutrition: The achievable imperative for global progress.*

UNICEF. (2020). *UNICEF's Conceptual Framework on the Determinants of Maternal and Child Nutrition.*

UNICEF, & WHO. (2021). *Indicators for assessing infant and young child feeding practices: definitions and measurement methods*.

UNICEF, WHO, FANTA, & USAID. (2017). *Meeting report on reconsidering, refining, and extending the World Health Organization infant and young child feeding indicators*. . https://data.unicef.org/wp-content/uploads/2017/11/IYCF-consultation-report-1.pdf

UNICEF, WHO, & World Bank Group. (2020). Joint Child Malnutrition Estimates.

Victora, C. G., Christian, P., Vidaletti, L. P., Gatica-Domínguez, G., Menon, P., & Black, R. E. (2021). Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda. *The Lancet*, *397*(10282), 1388-1399. https://doi.org/https://doi.org/10.1016/S0140-6736(21)00394-9

WHO. (2003). *Guiding principles for feeding breastfed children 6-24 months of age*.

WHO. (2005). *Guiding principles for feeding non-breastfed children 6-24 months of age*.

WHO, UNICEFF, IFPRI, UC Davis, & FANTA. (2008). *Macro International. Indicators for assessing infant and young child feeding practices*.

World Health Organization. (2016). *WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development*. http://www.who.int/childgrowth/standards/en/

Chapter 3: Temporal dietary diversity patterns are associated with child growth during the first two years in rural Vietnam.

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3.1 Abstract

Background: Complementary feeding represents a key window of opportunity to promote healthy child growth, but few research studies in low-and-middle-income countries have explored the changes and dynamics of diet quality during this period.

Objective: This study aims to characterize temporal dietary patterns between 6 and 23 months of age and assess their associations with child growth outcomes in rural Vietnam.

Method: Analyses used data from a prospective cohort (PRECONCEPT) and included 781 children that had dietary diversity data for four age windows: 6 – 8, 11 – 13, 17 – 19 and 23 – 25 months of age. We constructed temporal dietary diversity patterns by empirically tracking how minimum dietary diversity changed over the four age windows. The associations between dietary patterns and relative gain in weight and height between the first and last window were assessed in multivariate linear regressions with adjustment for baseline characteristics and birth outcomes.

Results: We identified two key aspects of diet quality, including the initiation of diverse diet and the stability of diverse diet. Based on these aspects, we characterized five temporal dietary diversity patterns: timely-stable, timely-unstable, delayed-stable, delayed-unstable and super-delayed. Less than 30% of the children in our sample followed timely-stable pattern. Compared to timely-stable pattern, timely-unstable pattern and super-delayed pattern are both associated with slower linear growth (β: -0.24; 95% CI: -043, -0.06, and β: - 0.25, 95% CI: -0.49, -0.02, respectively). Similarly, compared to timely-stable patter, others patterns are also associated with slower weight gain (timely-unstable pattern, β: - 0.25, 95% CI: -0.44, -0.07; delayed-stable pattern, β: - 0.35, 95% CI: -0.56, -0.14, and delayed-unstable pattern, β: - 0.23, 95% CI: -0.46, -0.01)

Conclusion: Many children did not start diverse diet at the recommended time between 6 and 8 months and/or maintain their diverse diet afterwards. These children may experience slower linear growth and weight gain. Future research should assess the scale of these sub-optimal dietary practices in other settings and design food access programs or behavioral change messages to address these problems.

3.2 Introduction

Complementary feeding period is a key window for children to establish a healthy diet and optimize child growth and development. This period marks an important transition from breastmilk to increasingly textured and tasteful food, which prepares children for their families' diet. During this period, children also acquire oral-motor skills needed for eating solid food such as biting and chewing, learn to express their hunger and satiety cues and develop food preferences and habits that can last through the life course (Daniels, 2019; Ventura & Worobey, 2013). The first two years of life is also the stage when children are most susceptible to growth faltering as a result of poor diet and repeated infections (Millward, 2017). Deficits in linear growth are difficult to regain after the first two years and can have long-lasting negative implications on future health and cognitive development (Adair et al., 2013; De Lucia Rolfe et al., 2018). Improving nutrition during the first 1000 days is critical for meeting Global Nutrition Targets and Sustainable Development Goals (UNICEFF, 2020; WHO, 2014).

However, there is a limited understanding of how early diet evolves during the complementary feeding period. Dietary intake is a repeated exposure that occurs over days, weeks and months, and its influence on health outcomes is likely to reflect the accumulation of dietary intake over time. It is thus ideal to understand and assess diet longitudinally. Such understanding will enable researchers and policy makers to characterize aspects of early life diet that can be targeted for programming and quantify the importance of early life diet on health and growth. In high-income countries, there have been several longitudinal studies that attempt to understand early life dietary patterns (Brazionis et al., 2012; Lim et al., 2016; Manohar et al., 2021; Smithers et al., 2013). These studies typically collected detailed dietary data such as 24-hr dietary recall or food frequency questionnaires, and commonly found several dietary patterns, including baby food pattern comprising of soft food such as pudding and cereals, discretionary pattern that includes unhealthy food like chocolate, biscuits and sweets and healthy pattern that includes diverse fresh food (Brazionis et al., 2012; Lim et al., 2016; Manohar et al., 2021; Smithers et al., 2013). These patterns have been showed to be associated with dietary patterns and risks of overweight and obesity in the later childhood (Group, 2015; Liberali et al., 2020; Min et al., 2021). In contrast, longitudinal studies on dietary patterns in early life are lacking in low-and-middle-

income countries (LMIC), where children are most vulnerable to undernutrition. One reason is the challenge and cost of collecting detailed dietary data, and thus new approaches are needed to assess temporal dietary data using available dietary measure in LMIC.

Dietary diversity has been widely collected in household surveys in LMIC using a simple questionnaire that counts the number of diverse nutrient-rich food that an individual consumes. The consumption of diverse food among young children is low in LMIC, partly because the current food system's low supply and high cost of nutrient-rich food such as meat, fruits and vegetables (Kachwaha et al., 2020; Siegel et al., 2014; Speedy, 2003). To monitor diverse food consumption in children, dietary diversity indicator was developed in 2007 by WHO and later revised in 2018 to include breastmilk in the count of nutrient-rich food. Based on the new guideline, only 27% of children in LMICs meet current WHO recommendations for a minimum diverse diet (MDD) (Gatica-Domínguez et al., 2021). Although dietary diversity has been showed to be a good proxy of micronutrient adequacy (Kennedy et al., 2007), systematic reviews have shown inconsistent relationships between dietary diversity and child growth across countries and called for more sensitive proxies of diet quality (Jones et al., 2014; Molani Gol et al., 2022). Constructing dietary measures longitudinally is one potential approach to create a stronger proxy of diet quality through incorporating the changes or stability of diet over time.

This present study takes a novel approach to track dietary diversity between 6 and 24 months of age using a longitudinal birth cohort in rural Vietnam. This study aims to construct *temporal dietary diversity patterns* in the first two years of age and to assess the associations between temporal dietary diversity patterns and child growth during the first 1000 days.

3.3 Method

Data source

Data were obtained from the offspring born to women who participated in a large randomized trial of preconception micronutrient supplement (PRECONCEPT study) (Nguyen et al., 2012). The trial was approved by the Ethical Committee of the Institute of Social and Medical Studies in Hanoi, Vietnam and

Emory University Institutional Review Boards. The trial was registered in the US Clinical Trials registry (NCT01665378) and written informed consent was obtained from all study participants.

At baseline, 5011 eligible women were identified from 20 communes located in four of Thai Nguyen's nine districts with primarily agricultural economies. These women were then randomly assigned into three groups to receive weekly containing either folate acid, iron and folate acid, or multiple micronutrients, and were followed prospectively to evaluate nutritional outcomes at birth and afterwards. At the first follow-up, a total of 1813 women conceived and 1599 had live births (1579 singletons and 10 twins) between 2012 and 2014. Afterwards, these newborns were followed-up several times up to age 2 years for anthropometry and dietary information. These follow-ups took place around 6, 9, 12, 15, 18 and 24 months after the first follow-up.

Sample selection

To create temporal dietary diversity patterns, we constructed panel data with the same number of children with diet data collected at several time points. Due to loss to follow-up and the variation in child age at each follow-up, we maximized the sample size by selecting four age windows, each a 3-month interval, including 6 – 8, 11 – 13, 17 – 19 and 23 – 25 months of age. We first selected children who had dietary diversity score at each of the four age windows above. If children had more than one dietary diversity scores measured during the same window, we randomly selected one score per window. Subsequently, we selected children that had data on dietary diversity and anthropometry at all 4 age windows and data on baseline and birth characteristics (Supplementary Figure 1). We assessed whether the children in the final sample is sufficiently homogenous in age by examining child age at each age window.

Variables

Temporal dietary diversity patterns: Diet data were collected using a questionnaire locally adapted from the standard WHO IYCF 2007 (WHO et al., 2008). Trained field workers interviewed mothers using a questionnaire consisted of Yes/No questions about whether her child consumed breastmilk or several pre-specified food groups in the last 24 hours. Pre-specified food groups included 8 liquid food groups such as plain water, fresh milk, fruit juice and sugar beverages and 17 solid food groups such as egg, tofu, land meat,

leafy vegetables and sugar snacks (cookies, biscuits and sweets). Breastfeeding and selected food or liquid food items were then aggregated to 8 food groups to derive dietary diversity score that ranged from 0 to 8 (UNICEF et al., 2017). To construct the temporal dietary diversity patterns, we first classified child diet at each window into two categories: meeting MDD (score 5 to 8) or below MDD (score 0 to 4). We then tracked how MDD changed over the four age windows. We expected to obtain 16 individual trends, given that we had 4 age windows and 2 dietary categories at each window (Table 1). These trends were then qualitatively examined and grouped into temporal patterns.

Growth measures: Child weight and length at each age window were collected by trained field staff using standard methods (Cogill, 2003). Child weight was measured using a UNICEF Beam type scale and recumbent length was measured with collapsible length boards, which were precise to 1 mm. The average of duplicate length and weight measurements was then converted into height-for-age Z-scores (HAZ), weight-for-age Z-scores (WAZ) and weight-for-height Z-scores (WHZ) according to 2006 WHO child growth standards (World Health Organization, 2016). These measurements were used to obtain conditional growth measures (primary outcomes) and anthropometry status indicators at 23 – 25 months of age (secondary outcomes), the latter including stunting, wasting and underweight. Conditional HAZ, WAZ and WHZ were calculated as the standardized residual from the ordinary least square of the respective z-score at 23 – 25 months of age (window 4) on the respective z-score at 6 – 8 months of age (window 1) with sex and age at the first window entered as the covariates (Horta et al., 2017). These standardized residuals capture the changes in height and weight not predicted by the initial height and weight. Thus, they are not correlated with the initial height and weight, nor with any observed or unobserved factors occurring before 6 – 8 months that influenced initial height and weight. Such approach allowed us to control for both observed and unobserved baseline socioeconomics and birth outcomes, and were deemed more robust than other approaches. One other approach is to model the differences in z-scores between the two age windows but this approach induces the phenomenon of regression to the mean, whereby children with very low (or very high) z-score at the initial window tend to have increased (or decreased) z-score subsequently. The other approach is to

model the z-score at the last window controlling for the z-scores at the first window and other covariates, but unobserved socioeconomic baseline factors are not controlled for in the resulting model.

Covariates: We included the following baseline socioeconomic and birth outcome data in our analyses: child sex, gestational age (weeks), birth weight (kilograms), maternal age at baseline (years), maternal ethnicity (Kinh vs. minor ethnicities), maternal education (secondary or lower vs. vocational training or higher), household food security (secured vs. insecure), household wealth tertile (low, middle vs. high) and intervention arms (folic acid, iron-folic acid, and multiple micronutrient supplements). Wealth tertiles were derived from the first component of the principal component analysis of household assets ownership, an approach commonly used in the Demographic and Health Surveys (Rutstein & Johnson, 2004) while food security status was measured using the USDA Household Food Security Survey Module (Coates et al., 2007).

Statistical analysis

We first described baseline socioeconomics and birth outcomes of our analytical sample. We also compared the distribution of these characteristics between the children included for our analytical sample and children who were excluded by using chi-square tests for categorical variables and one-way ANOVA test for continuous variables. Afterwards, we described the temporary dietary diversity patterns that we identified and explored how these patterns differ in the distribution of baseline socioeconomic, birth outcomes and consumption of individual food groups.

To examine the associations between growth measures and temporal dietary patterns, we visualized how growth measures (conditional growth and anthropometry status) differed by temporal patterns and ran ANOVA tests for conditional growth measures and chi-square tests for anthropometry status at 23 – 25 months of age to assess the overall difference in growth measures across dietary pattern categories.

Prior to modeling, we calculated the intra-cluster correlation coefficients to assess the effect of the cluster sample design whereby children were enrolled from 20 communes on anthropometry measures, and found no evidence of such clustering. Thus, multivariate linear regressions were used to model the associations between temporal dietary patterns and conditional growth. Similarly, multivariate logistic regressions were

used to model the effects of temporal dietary patterns on anthropometry status at 23 – 25 months of age. Lastly, we examined whether the effects of temporal dietary patterns on growth are modified by the baseline nutritional status by including the interaction terms between temporal dietary patterns and baseline nutritional status and obtaining the overall p-value of the interactions from the Type 3 ANOVA test. In all these models, we contrasted all dietary patterns against the most optimal dietary pattern to understand the effects of deviating away from a healthy, optimal diet on growth.

3.4 Results

Of 1599 live births, dietary diversity scores were measured for 1212 children between 6 – 8 months of age, 1204 children between 11 – 13 months, 1412 children between 17 – 19 months and 1193 children between 23 – 25 months (Supplementary Figure 1). Of these children, 805 children had dietary data for all four age windows and were included in the analysis. After excluding children with missing data of key variables (weight, height, baseline socioeconomics and birth outcomes), we obtained a final analytical sample of 781. We assessed the heterogeneity in age within each age window and found that mean age (SD) was 6.7 (0.8) months in the first window, 12.7 (0.6) months in the second window, 18.5 (0.4) months in the third window and 24.4 (0.4) months in the last window. These results suggest that the variation in age within each window was sufficiently small to enable longitudinal tracking of diet.

Of 781 children in our analytical sample, 54% were male and the mean (SD) birth weight was 3.0 (0.4) kg. Half of the children had mothers from minor ethnicities, 61% of the children had mothers with education level more than secondary and about two-thirds came from food secured households (Supplementary Table 1). Except for maternal age and child sex, all characteristics of the analytic sample were similar to those lost to follow up (Supplemental Table 1).

Temporal dietary diversity patterns

The prevalence of children with MDD was 57% in the first window, 78% in the second window, 80% in the third window and 70% in the last window. By tracking MDD over the four windows, we obtained a total of 16 trends of dietary diversity over time (Table 1). These trends are characterized by two main attributes. The

first is the timing when MDD is initiated, defined as timely if MDD was initiated at the recommended period between 6 and 8 months, delayed if MDD was initiated around 12 months and super-delayed if MDD was initiated afterwards. The second attribute is the stability of MDD, which indicates whether children maintained MDD after it was initiated. Based on these attributes, we grouped children into five temporal dietary diversity patterns: timely-stable (n = 237, 30%), timely-unstable (n = 207, 27%), delayed-stable (n = 127, 16%), delayed-unstable (n = 118, 15%) and super-delayed (n = 92, 12%). Since only 12% of the children in our sample followed the super-delayed pattern, we did not divide this pattern by the stability of MDD. The super-delayed pattern is deemed to be the least favorable one, as the MDD was not given to children until they were between 18 and 24 months of age. In contrast, the timely-stable pattern was deemed to be the most optimal pattern, as children in this pattern had MDD at the recommended period between 6 to 8 month and maintained a diverse diet throughout the first two years.

Compared to other patterns, children belonging to timely-stable pattern (most optimal pattern) were born with a larger birth weight, came from higher-income households, and had a higher share of mothers from the major ethnicity (Kinh) or with more than secondary education (Table 2). Children with a timely-stable pattern were also slightly older than children with other patterns during the first and the second age windows. In specific, they were around 0.4 months (12 days) or 0.2 months (6 days) older than other patterns in the first and second window, respectively.

Food consumption differed between the five dietary patterns except for breastfeeding and grain consumption (Figure 1). Breastfeeding was universal in the first year but dropped sharply afterwards while grain consumption was high across all windows. With regards to dairy, flesh food and vitamin A fruits and vegetables, the consumption was initially higher among the timely-stable and timely-unstable patterns than other patterns but then steadily increased such that all patterns converged to a high level (> 80%) in the second year. In contrast, the consumption of egg, legume and other fruits and vegetables were overall low and fluctuating such that the consumption in the last window remain modest (20% - 60%) and highly varied across patterns. Sugar snacks and sugar-sweetened beverages followed similar trends for all patterns with

overall low consumption of sugar-sweetened beverages (3% - 10%) and sharply rising consumption of sugar snacks (from 20% in the first year to 60% in the second year).

Associations between growth measures and temporal dietary diversity patterns

Mean conditional growth measures by dietary patterns were visualized in Figure 2. Overall, children with timely-stable pattern had the largest gains in HAZ and WAZ, but not in WHZ. Compared to timely-stable pattern (the most optimal pattern), timely-unstable and super-delayed patterns are strongly associated with smaller gains in HAZ (β: -0.24, 95% CI: -0.43, -0.06 and β: -0.25, 95% CI: -0.49, -0.02, respectively) (Table 3). Suboptimal diet patterns are all associated with lower gain in WAZ as compared to timely-stable pattern with coefficients of -0.25 (95% CI: -0.44, -0.07) for timely unstable, -0.35 (95% CI: -0.56, -0.14) for delayed stable and -0.23 (95% CI: -0.46, -0.01) for delayed unstable patterns. In the model predicting conditional WHZ, only delayed-stable pattern was found to be associated with smaller gain in WHZ than the timely-stable pattern (β: -0.29, 95% CI: -0.51, -0.08). There was evidence that the effects of dietary patterns on conditional WAZ are modified by WAZ at 6 – 8 months (overall p-value = 0.013). In specific, the effects of deviating away from optimal diet on slower conditional WAZ is stronger in children who were heavier at 6 – 8 months, but this effect is only observed for delayed-unstable patterns. There was no evidence of effect modification by HAZ and WHZ at 6 – 8 months (results not shown).

Overall, the prevalence of stunting, underweight and wasting at 23-25 months were 22%, 7% and 2% respectively (Figure 3). The timely-stable pattern had the lowest prevalence of stunting and wasting, but not underweight. In the adjusted model predicting stunting at 23 – 25 months (Table 4), timely-unstable and super-delayed patterns were associated with 1.78 (95% CI: 1.05, 3.04) and 1.98 (95% CI: 1.02, 3.80) higher odds of stunting. No associations were found for wasting or underweight.

3.5 Discussion

In this study, we identify two key aspects of diet quality, including the initiation of diverse diet and the stability of diverse diet over time. Based on these aspects, we characterized five temporal dietary diversity patterns: timely-stable, timely-unstable, delayed-stable, delayed-unstable and super-delayed. Only a third of

the children in our sample followed the timely-stable pattern, which was deemed the optimal pattern. We showed that the remaining two-thirds of the children, who followed sub-optimal dietary patterns, experienced impaired growth between 6 and 24 months of age.

Our results indicate that a serious problem in child nutrition in this context is the delayed initiation of diverse diet rather than the delayed initiation of any complementary food. Theoretically, timely exposure to diverse diet supports optimal child nutrition in several ways. First, it provides micronutrients needed for linear growth such as iron, zinc, vitamin B12 and vitamin A (Millward, 2017). Secondly, the diversity of diet supports the development of mature, diverse and stable gut microbiome in young children (Homann et al., 2021), which predicts faster gain in weight and height (Blanton et al., 2016; Subramanian et al., 2014). Lastly, timely exposure to diverse food influences children's perception of flavor, taste and texture and increase their preferences for healthy food later in life (Beauchamp & Mennella, 2009). A growing body of literature in high-income countries have indicated that exposing infants to food rich in flavors and texture such as fruits and vegetables improved food acceptance of fruits and vegetables during the school-age period (Coulthard et al., 2009; Nicklaus, 2016).

Despite the importance of timely exposure to diverse diet, just over half of the children in our sample were given a minimum diverse diet between 6 and 8 months, although they all started solid food in this period. This result reflects the global situation, which showed a large gap between children with timely start of any complementary food (72%) and children with timely start of minimum diverse diet (29%) (Global Nutrition Report, 2020). This gap is driven by both supply and demand factors. Supply factors include the higher cost and lower availability of animal-sourced food and fruits and vegetables as compared to cereals. For example, per-capita production and consumption of animal-sourced food was low and has been declining in several low-income countries despite the global increasing trend (Speedy, 2003). Similarly, the global production of fruits and vegetables has increased steadily (FAO), but fell 22% short of the nutritional need of the global population (Siegel et al., 2014). Additionally, the nutritious diet comprising of animal-sourced food, and fruits and vegetables is estimated to be twice expensive than the cereal-based diet (Kachwaha et al., 2020). Demand factors include the lack of awareness among caregivers about the importance of fruits, vegetables, eggs and

meat for child growth and health, the misconceptions that some of these foods can cause choking or delayed speech development in children, or the cultural norms against meat consumption in some nomadic cultures or religions (Dickin et al., 2021). These supply and demand factors point to the need to assess the prevalence of delayed diverse diet in other settings and its impact on child growth.

Based on our findings, the instability of minimum diverse diet is another challenge in ensuring diet quality in early life. In our sample, of all children who started the minimum diverse diet by the first birthday, about half did not maintain this diet consistently. Although day-to-day variability of diet is expected, falling below the minimum diverse diet might put children at risk of micronutrient inadequacy (Verger et al., 2021). As illustrated in our study, these children may also experience slower growth. For example, among children who started diverse diet timely, the failure to maintain diverse diet consistently is associated with 0.24 z-score lower in conditional HAZ and 0.25 z-score lower in conditional WAZ. The challenge to maintain diverse diet throughout may involve both the seasonality of food supply and the changes in child eating behaviors. Fluctuation of fresh food supply have been well documented as a major concern among smallholder farmers in LMIC, which often has consequences on household and child dietary diversity (Bonuedi et al., 2021; Broaddus-Shea et al., 2018). A recent qualitative study in Vietnam showed that the seasonality of food supply was not only due to the natural growing cycle of most of the fruits and vegetables plants and livestock, but it also reflects the poor harvest of cash crops during lean season, which leads to deficit in cash income needed to purchase food (Duong et al., 2022). Addressing the seasonality of food supply may involve the promotion of diverse food production to ensure the supply of fresh food throughout the year, and programs to support farmers to earn off-farm incomes during lean season. Failure to consume diverse diet consistently may also reflect the fluctuation in young children's eating behaviors. Over the weaning period, children fine-tune their oral-motor skills required for eating and start to form their food preference while navigating caregivers' feeding behaviors to communicate their hunger and satiety (Ross, 2017), which explain the day-to-day variability in their food acceptance and fussiness (McNally et al., 2016; Young & Drewett, 2000). The changes in eating mood and temperament in preschool-aged children were cited as concern by several mothers,

according to the study in Vietnam(Duong et al., 2022), but to which extent these changes influence diet in the first two years merits further examination.

Here we demonstrate that qualitative assessment of repeated dietary indicators can be a valuable approach to understand and assess diet quality. Cross-sectional measures of diet quality are limited because they are not sensitive to assess causal link with health outcomes or track program effectiveness (Jones et al., 2014; Verger et al., 2021), and not able to capture the variability in diet. Assessing longitudinal measures of diet indicators, as done in our study, provided insights to different aspects of diet that are important in predicting nutritional outcomes. Similar approach can be applied to other dietary indicators, such as women and household dietary diversity (Azene et al., 2021; Savy et al., 2006), food variety score (a count of food items out of all possible healthy food items eaten) (Hatløy et al., 1998; Steyn et al., 2006) or recently developed global diet quality score (a food-based metric consisting of 25 food groups, designed to predict both under- and overnutrition risks) (Sabri et al., 2021). Such approach is particularly desirable in settings where food supply or household food access fluctuates over the year or in programs targeting populations that experience significant dietary changes such as preschool ages, adolescents, pregnancy or patients.

This approach can also be used to assess the temporality of unhealthy food patterns and their relation with overnutrition outcomes. In our study setting, less than 5% of the participating children consumed sugar-sweetened drinks but 20% of these children consumed sugar snacks such as biscuits, cookies and chocolate in the first year, and this number rose to 80% in the second year. Other studies of children aged 6 and 23 months also noted a similar level of sugar snack consumption, which ranged between 19% in rural Burkina Faso and 80% in rural India, but these studies found a higher level of sugar-sweetened beverages consumption, ranging between 9% in rural Mali and 12% in rural Indonesia, than what was seen in this study (Green et al., 2019; Nordhagen et al., 2019; Sirkka et al., 2022). The consumption of these nutrient-poor food increased sharply over the period between 1 and 6 years of age (Green et al., 2019), which might place children at risk of consuming inadequate nutrient-dense food and developing overweight and obesity later in life (Pries, Filteau, et al., 2019; Pries, Rehman, et al., 2019). Assessing unhealthy food consumption is beyond the scope of the parent study and may be less relevant to our study context, in which just 10% of the children

became overweight at 6 to 7 years of age. However, tracking temporal patterns in unhealthy food consumption is warranted in settings where children are at high risk of dual burden of malnutrition.

Our findings inform programs that target child diet quality in settings similar to rural Vietnam in several ways. First, while the revised infant and young child feeding guidelines include the indicator of solid food introduction, this specific indicator may not be relevant to the rural settings of countries experiencing rapid economic growth and agricultural investment like Vietnam, where children might all started cereal-based food by 6 – 8 months. Rather, the behavioral change messaging should emphasize the timely introduction of nutrient-rich food such as egg, meat and fruits and vegetables. Specifically, formative research might be needed to understand why certain food such as egg and non-vitamin A fruits and vegetables were not commonly given to children throughout the first two years, as contrast to certain food groups such as lean meat and dairy, which were not common food in the first year but eventually consumed by all children in the second year. Secondly, given that many children may not maintain diverse diet in the first two years, programs on the one hand should attempt to measure dietary indicators over time to best evaluate the program success, and on the other hand identify strategies to support the stability of diverse diet. The stability of diverse diet may reflect the stability of the broader food environment, which can be supported through farming practices such as crop rotation or diversified farming to ensure stable fresh food supply combined with programs that generate off-farm incomes during lean season.

A key strength of our study is the longitudinal study design with rich data on nutritional status and dietary recall, which enabled the assessment of temporal dietary diversity and conditional growth. Another major strength is our use of conditional growth measures. Conditional measures represent children's deviation from their expected size and are thus uncorrelated with the initial child size. Such approach allows us to control for unobserved factors that affect initial child size such as road access, water and sanitation and livestock ownership, which are not collected in the study or not sufficiently measured using the study's covariates.

Our study also has several limitations. First, our use of 3-month interval to construct age window may introduce bias because the variation in diet quality within the same age window may be driven by the variation

in age. However, this is unlikely because children following timely-stable pattern (most optimal pattern) were older than other children following other patterns by around 0.4 months (12 days) or 0.2 months (6 days) in the first and second age window, respectively. These differences were small, suggesting that children are sufficiently homogenous in age within the same age window. Second, this analysis included a subset of the birth cohort (49%) since the primary age window of the original study was 12 and 24 months of age. Children included in our analysis may differ from the birth cohort in some characteristics that modify the relation between diet and growth. However, we show that this likelihood is low because there were no differences in the baseline and birth characteristics between the sample of children included in this analysis and the sample of children who were not.

In conclusion, our study demonstrates the use of qualitative assessment of repeated dietary indicators to construct temporal dietary patterns. Using this novel approach, we identified several temporal dietary diversity patterns and revealed two key challenges to early life's diet quality: the delayed initiation of diverse diet and the instability of diverse diet over time. Children with optimal diet should start diverse diet timely and maintain it throughout their early childhood, but about two-thirds of the children in our sample did not follow this optimal diet and these children experienced a slower relative growth. Whether delayed initiation and instability of diverse diet are also common in other settings and how these problems affect health and growth measures merits further investigation. Future programs aiming to improve diet in young children in settings similar to rural Vietnam should integrate messages to emphasize the initiation and maintenance of diverse diet.

3.6 References

Adair, L. S., Fall, C. H. D., Osmond, C., Stein, A. D., Martorell, R., Ramirez-Zea, M., Sachdev, H. S., Dahly, D. L., Bas, I., Norris, S. A., Micklesfield, L., Hallal, P., & Victora, C. G. (2013). Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: findings from five birth cohort studies. *The Lancet*, *382*(9891), 525-534. https://doi.org/https://doi.org/10.1016/S0140-6736(13)60103-8

Azene, A. G., Aragaw, A. M., Wubetie, H. T., Wassie, G. T., Tsegaye, G. W., Derebe, M. A., & Mitiku, H. D. (2021). Dietary diversity among pregnant women and associated factors in Ethiopia: Systematic review and meta-analysis. *Plos One*, *16*(6), e0251906. https://doi.org/10.1371/journal.pone.0251906

Beauchamp, G. K., & Mennella, J. A. (2009). Early flavor learning and its impact on later feeding behavior. *Journal of Pediatric Gastroenterology and Nutrition*, *48 Suppl 1*, S25-30. https://doi.org/https://doi.org/10.1097/MPG.0b013e31819774a5

Blanton, L. V., Charbonneau, M. R., Salih, T., Barratt, M. J., Venkatesh, S., Ilkaveya, O., Subramanian, S., Manary, M. J., Trehan, I., Jorgensen, J. M., Fan, Y. M., Henrissat, B., Leyn, S. A., Rodionov, D. A., Osterman, A. L., Maleta, K. M., Newgard, C. B., Ashorn, P., Dewey, K. G., & Gordon, J. I. (2016). Gut bacteria that prevent growth impairments transmitted by microbiota from malnourished children. *Science*, *351*(6275). https://doi.org/10.1126/science.aad3311

Bonuedi, I., Kornher, L., & Gerber, N. (2021). Agricultural seasonality, market access, and food security in Sierra Leone. *Food Security*. https://doi.org/https://doi.org/10.1007/s12571-021-01242-z

Brazionis, L., Golley, R. K., Mittinty, M. N., Smithers, L. G., Emmett, P., Northstone, K., & Lynch, J. W. (2012). Characterization of transition diets spanning infancy and toddlerhood: a novel, multiple-time-point application of principal components analysis. *The American Journal of Clinical Nutrition*, *95*(5), 1200-1208. https://doi.org/10.3945/ajcn.111.026575

Broaddus-Shea, E. T., Thorne-Lyman, A. L., Manohar, S., Nonyane, B. A. S., Winch, P. J., & West, K. P., Jr. (2018). Seasonality of Consumption of Nonstaple Nutritious Foods among Young Children from Nepal's 3 Agroecological Zones. *Curr Dev Nutr*, *2*(9), nzy058. https://doi.org/10.1093/cdn/nzy058

Coates, J., Swindale, A., & Bilinsky, P. (2007). *Household Food Insecurity Access Scale (HFIAS) for Measurement of Household Food Access: Indicator Guide (v. 3).*

Cogill, B. (2003). *Anthropometric indicators measurement guide: Food and Nutrition Technical Assistance Project*.

Coulthard, H., Harris, G., & Emmett, P. (2009). Delayed introduction of lumpy foods to children during the complementary feeding period affects child's food acceptance and feeding at 7 years of age. *Maternal & Child Nutrition*, *5*(1), 75-85. https://doi.org/https://doi.org/10.1111/j.1740-8709.2008.00153.x

Daniels, L. A. (2019). Feeding Practices and Parenting: A Pathway to Child Health and Family Happiness. *Annals of Nutrition and Metabolism*, *74(suppl 2)*(2), 29-42. https://doi.org/10.1159/000499145

De Lucia Rolfe, E., de França, G. V. A., Vianna, C. A., Gigante, D. P., Miranda, J. J., Yudkin, J. S., Horta, B. L., & Ong, K. K. (2018). Associations of stunting in early childhood with cardiometabolic risk factors in adulthood. *Plos One*, *13*(4), e0192196. https://doi.org/10.1371/journal.pone.0192196

Dickin, K. L., Litvin, K., McCann, J. K., & Coleman, F. M. (2021). Exploring the Influence of Social Norms on Complementary Feeding: A Scoping Review of Observational, Intervention, and Effectiveness Studies. *Current developments in nutrition*, *5*(2). https://doi.org/https://doi.org/10.1093/cdn/nzab001

Duong, C., Jenkins, M., Pyo, E., Nguyen, P.-H., Huynh, T. T. T., Nguyen-Viet, H., Young, M. F., & Ramakrishnan, U. (2022). Understanding maternal food choice for preschool children across urban-rural settings in Vietnam. *Maternal & Child Nutrition*, *In-press*.

FAO. *FAOSTAT - Crops and livestock products* https://www.fao.org/faostat/en/#data/QCL

Gatica-Domínguez, G., Neves, P. A. R., Barros, A. J. D., & Victora, C. G. (2021). Complementary Feeding Practices in 80 Low- and Middle-Income Countries: Prevalence of and Socioeconomic Inequalities in Dietary Diversity, Meal Frequency, and Dietary Adequacy. *J Nutr*, *151*(7), 1956-1964. https://doi.org/10.1093/jn/nxab088

Global Nutrition Report. (2020). *Country Nutrition Profiles*. Retrieved December from https://globalnutritionreport.org/resources/nutrition-profiles/

Green, M., Hadihardjono, D. N., Pries, A. M., Izwardy, D., Zehner, E., & Huffman, S. L. (2019). High proportions of children under 3 years of age consume commercially produced snack foods and sugar-sweetened beverages in Bandung City, Indonesia. *Matern Child Nutr*, *15 Suppl 4*(Suppl 4), e12764. https://doi.org/10.1111/mcn.12764

Group, E. M. C. C. S. (2015). Dietary Patterns Track from Infancy to Preschool Age: Cross-Sectional and Longitudinal Perspectives. *The Journal of Nutrition*, *145*(4), 775-782. https://doi.org/10.3945/jn.114.201988

Hatløy, A., Torheim, L. E., & Oshaug, A. (1998). Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. *Eur J Clin Nutr*, *52*(12), 891-898. https://doi.org/10.1038/sj.ejcn.1600662

Homann, C. M., Rossel, C. A. J., Dizzell, S., Bervoets, L., Simioni, J., Li, J., Gunn, E., Surette, M. G., de Souza, R. J., Mommers, M., Hutton, E. K., Morrison, K. M., Penders, J., van Best, N., & Stearns, J. C. (2021). Infants' First Solid Foods: Impact on Gut Microbiota Development in Two Intercontinental Cohorts. *Nutrients*, *13*(8). https://doi.org/10.3390/nu13082639

Horta, B. L., Victora, C. G., de Mola, C. L., Quevedo, L., Pinheiro, R. T., Gigante, D. P., Motta, J., & Barros, F. C. (2017). Associations of Linear Growth and Relative Weight Gain in Early Life with Human Capital at 30 Years of Age. *J Pediatr*, *182*, 85-91.e83. https://doi.org/10.1016/j.jpeds.2016.12.020

Jones, A. D., Ickes, S. B., Smith, L. E., Mbuya, M. N., Chasekwa, B., Heidkamp, R. A., Menon, P., Zongrone, A. A., & Stoltzfus, R. J. (2014). World Health Organization infant and young child feeding indicators and their associations with child anthropometry: a synthesis of recent findings. *Matern Child Nutr*, *10*(1), 1-17. https://doi.org/10.1111/mcn.12070

Kachwaha, S., Nguyen, P. H., DeFreese, M., Avula, R., Cyriac, S., Girard, A., & Menon, P. (2020). Assessing the Economic Feasibility of Assuring Nutritionally Adequate Diets for Vulnerable Populations in Uttar Pradesh, India: Findings from a "Cost of the Diet" Analysis. *Current developments in nutrition*, *4*(12), nzaa169. https://doi.org/10.1093/cdn/nzaa169

Kennedy, G. L., Pedro, M. R., Seghieri, C., Nantel, G., & Brouwer, I. (2007). Dietary Diversity Score Is a Useful Indicator of Micronutrient Intake in Non-Breast-Feeding Filipino Children. *The Journal of Nutrition*, *137*(2), 472-477. https://doi.org/10.1093/jn/137.2.472

Liberali, R., Kupek, E., & Assis, M. A. A. (2020). Dietary Patterns and Childhood Obesity Risk: A Systematic Review. *Child Obes*, *16*(2), 70-85. https://doi.org/10.1089/chi.2019.0059

Lim, G. H., Toh, J. Y., Aris, I. M., Chia, A.-R., Han, W. M., Saw, S. M., Godfrey, K. M., Gluckman, P. D., Chong, Y.-S., Yap, F., Lee, Y. S., Kramer, M. S., & Chong, M. F.-F. (2016). Dietary Pattern

Trajectories from 6 to 12 Months of Age in a Multi-Ethnic Asian Cohort. *Nutrients*, *8*(6), 365. https://doi.org/10.3390/nu8060365

Manohar, N., Hayen, A., Do, L., Scott, J., Bhole, S., & Arora, A. (2021). Early life and socio-economic determinants of dietary trajectories in infancy and early childhood – results from the HSHK birth cohort study. *Nutrition Journal*, *20*(1), 76. https://doi.org/10.1186/s12937-021-00731-3

McNally, J., Hugh-Jones, S., Caton, S., Vereijken, C., Weenen, H., & Hetherington, M. (2016). Communicating hunger and satiation in the first 2 years of life: a systematic review. *Matern Child Nutr*, *12*(2), 205-228. https://doi.org/10.1111/mcn.12230

Millward, D. J. (2017). Nutrition, infection and stunting: the roles of deficiencies of individual nutrients and foods, and of inflammation, as determinants of reduced linear growth of children. *Nutrition Research Reviews*, *30*(1), 50-72. https://doi.org/https://doi.org/10.1017/s0954422416000238

Min, K., Wang, J., Liao, W., Astell-Burt, T., Feng, X., Cai, S., Liu, Y., Zhang, P., Su, F., Yang, K., Sun, L., Zhang, J., Wang, L., Liu, Z., & Jiang, Y. (2021). Dietary patterns and their associations with overweight/obesity among preschool children in Dongcheng District of Beijing: a cross-sectional study. *Bmc Public Health*, *21*(1), 223. https://doi.org/10.1186/s12889-021-10240-x

Molani Gol, R., Kheirouri, S., & Alizadeh, M. (2022). Association of Dietary Diversity With Growth Outcomes in Infants and Children Aged Under 5 Years: A Systematic Review. *Journal of Nutrition Education and Behavior*, *54*(1), 65-83. https://doi.org/10.1016/j.jneb.2021.08.016

Nguyen, P. H., Lowe, A. E., Martorell, R., Nguyen, H., Pham, H., Nguyen, S., Harding, K. B., Neufeld, L. M., Reinhart, G. A., & Ramakrishnan, U. (2012). Rationale, design, methodology and sample characteristics for the Vietnam pre-conceptual micronutrient supplementation trial (PRECONCEPT): a randomized controlled study. *Bmc Public Health*, *12*, 898. https://doi.org/10.1186/1471-2458-12-898

Nicklaus, S. (2016). 13 - Relationships between early flavor exposure, and food acceptability and neophobia. In P. Etiévant, E. Guichard, C. Salles, & A. Voilley (Eds.), *Flavor* (pp. 293-311). Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-0-08-100295-7.00014-1

Nordhagen, S., Pries, A. M., & Dissieka, R. (2019). Commercial Snack Food and Beverage Consumption Prevalence among Children 6-59 Months in West Africa. *Nutrients*, *11*(11). https://doi.org/10.3390/nu11112715

Pries, A. M., Filteau, S., & Ferguson, E. L. (2019). Snack food and beverage consumption and young child nutrition in low- and middle-income countries: A systematic review. *Matern Child Nutr*, *15 Suppl 4*(Suppl 4), e12729. https://doi.org/10.1111/mcn.12729

Pries, A. M., Rehman, A. M., Filteau, S., Sharma, N., Upadhyay, A., & Ferguson, E. L. (2019). Unhealthy Snack Food and Beverage Consumption Is Associated with Lower Dietary Adequacy and Length-for-Age z-Scores among 12-23-Month-Olds in Kathmandu Valley, Nepal. *J Nutr*, *149*(10), 1843-1851. https://doi.org/10.1093/jn/nxz140

Ross, E. (2017). Chapter 9 - Eating Development in Young Children: Understanding the Complex Interplay of Developmental Domains. In J. M. Saavedra & A. M. Dattilo (Eds.), *Early Nutrition and Long-Term Health* (pp. 229-262). Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-0-08-100168-4.00009-4

Rutstein, S., & Johnson, K. (2004). *The DHS wealth index. DHS Comparative Reports No. 6*. Retrieved May from https://dhsprogram.com/pubs/pdf/CR6/CR6.pdf.

Sabri, B., Walter, W., & Megan, D. (2021). *Developing and validating a food-based global diet quality score* (Sight and Life report, Issue.

Savy, M., Martin-Prével, Y., Traissac, P., Eymard-Duvernay, S., & Delpeuch, F. (2006). Dietary Diversity Scores and Nutritional Status of Women Change during the Seasonal Food Shortage in Rural Burkina Faso. *The Journal of Nutrition*, *136*(10), 2625-2632. https://doi.org/10.1093/jn/136.10.2625

Siegel, K. R., Ali, M. K., Srinivasiah, A., Nugent, R. A., & Narayan, K. M. V. (2014). Do We Produce Enough Fruits and Vegetables to Meet Global Health Need? *Plos One*, *9*(8), e104059. https://doi.org/10.1371/journal.pone.0104059

Sirkka, O., Abrahamse-Berkeveld, M., & van der Beek, E. M. (2022). Complementary Feeding Practices among Young Children in China, India, and Indonesia: A Narrative Review. *Current developments in nutrition*, *6*(6), nzac092. https://doi.org/10.1093/cdn/nzac092

Smithers, L. G., Golley, R. K., Mittinty, M. N., Brazionis, L., Northstone, K., Emmett, P., & Lynch, J. W. (2013). Do dietary trajectories between infancy and toddlerhood influence IQ in childhood and adolescence? Results from a prospective birth cohort study. *Plos One*, *8*(3), e58904-e58904. https://doi.org/10.1371/journal.pone.0058904

Speedy, A. W. (2003). Global Production and Consumption of Animal Source Foods. *The Journal of Nutrition*, *133*(11), 4048S-4053S. https://doi.org/10.1093/jn/133.11.4048S

Steyn, N. P., Nel, J. H., Nantel, G., Kennedy, G., & Labadarios, D. (2006). Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Nutrition*, *9*(5), 644-650. https://doi.org/10.1079/PHN2005912

Subramanian, S., Huq, S., Yatsunenko, T., Haque, R., Mahfuz, M., Alam, M. A., Benezra, A., DeStefano, J., Meier, M. F., Muegge, B. D., Barratt, M. J., VanArendonk, L. G., Zhang, Q., Province, M. A., Petri, W. A., Jr., Ahmed, T., & Gordon, J. I. (2014). Persistent gut microbiota immaturity in malnourished Bangladeshi children. *Nature*, *510*(7505), 417-421. https://doi.org/10.1038/nature13421

UNICEF, WHO, FANTA, & USAID. (2017). *Meeting report on reconsidering, refining, and extending the World Health Organization infant and young child feeding indicators*. . https://data.unicef.org/wp-content/uploads/2017/11/IYCF-consultation-report-1.pdf

UNICEFF. (2020). *Global action plan on wasting: A framework for action to accelerate progress in preventing and managing child wasting and the achievement of the Sustainable Development Goals*.

Ventura, Alison K., & Worobey, J. (2013). Early Influences on the Development of Food Preferences. *Current Biology*, *23*(9), R401-R408. https://doi.org/10.1016/j.cub.2013.02.037

Verger, E. O., Le Port, A., Borderon, A., Bourbon, G., Moursi, M., Savy, M., Mariotti, F., & Martin-Prevel, Y. (2021). Dietary Diversity Indicators and Their Associations with Dietary Adequacy and Health

Outcomes: A Systematic Scoping Review. *Advances in Nutrition*, *12*(5), 1659-1672. https://doi.org/10.1093/advances/nmab009

WHO. (2014). *Global nutrition targets 2025: stunting policy brief.* (WHO/NMH/NHD/14.3., Issue.

WHO, UNICEFF, IFPRI, UC Davis, & FANTA. (2008). *Macro International. Indicators for assessing infant and young child feeding practices*.

World Health Organization. (2016). *WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development*. http://www.who.int/childgrowth/standards/en/

Young, B., & Drewett, R. (2000). Eating behaviour and its variability in 1-year-old children. *Appetite*, *35*(2), 171-177. https://doi.org/https://doi.org/10.1006/appe.2000.0346

3.7 Figures & tables

Table 1: Temporal dietary diversity patterns in a sample of birth cohort in rural Vietnam

Trends	Minimum dietary diversity over 4 age windows (X indicates meeting minimum dietary diversity recommendation)				Number of children	Temporal dietary diversity patterns
	6 – 8 months	11 – 13 months	17 – 19 months	23 – 25 months		
1	X	X	X	X	237	Timely-stable (n = 237, 30%)
2	X	X	X		72	Timely-unstable (n = 207, 27%)
3	X	X		X	42	
4	X	X			16	
5	X		X	X	40	
6	X		X		18	
7	X			X	11	
8	X				8	
9		X	X	X	127	Delayed-stable (n = 127, 16%)
10		X	X		63	Delayed-unstable (n = 118, 15%)
11		X		X	36	
12		X			19	
13			X	X	39	Super-delayed (92, 12%)
14			X		27	
15				X	13	
16					13	

Table 2: Baseline characteristics and birth outcomes of the birth cohort in rural Vietnam by temporal dietary diversity patterns

Covariates[1]	Temporal dietary diversity patterns				
	Timely-stable (n = 237)	Timely-unstable (n = 207)	Delayed-stable (n = 127)	Delayed-unstable (n = 118)	Super-delayed (n = 92)
Child characteristics					
Sex (= Female)[2]	91 (44.0)	59 (46.5)	56 (47.5)	35 (38.0)	118 (49.8)
Age at window 1 (months) ***	7.1 (0.8)	6.9 (0.8)	6.7 (0.5)	6.8 (0.6)	7.1 (0.9)
Age at window 2 (months) *	12.8 (0.6)	12.6 (0.5)	12.7 (0.4)	12.6 (0.5)	12.7 (0.6)
Age at window 3 (months)	18.5 (0.4)	18.6 (0.4)	18.5 (0.4)	18.5 (0.4)	18.5 (0.4)
Age at window 4 (months)	24.4 (0.4)	24.4 (0.4)	24.4 (0.4)	24.3 (0.4)	24.4 (0.5)
Gestational age (weeks)	39.2 (1.8)	39.1 (2.0)	39.1 (2.0)	39.3 (2.0)	39.3 (2.0)
Birth weight (kilogram) *	31.3 (3.9)	30.9 (4.4)	30.0 (3.9)	30.7 (4.0)	31.3 (4.3)
Maternal and household characteristics					
Maternal age at baseline (years)	26.6 (4.4)	26.2 (4.5)	26.6 (4.4)	25.4 (4.7)	25.7 (4.4)
Maternal ethnicity (= Minor ethnicities)[2] ***	143 (60.3)	96 (46.4)	62 (48.8)	40 (33.9)	43 (46.7)
Maternal education (= Secondary education or lower)[2] **	108 (45.6)	82 (39.6)	50 (39.4)	34 (28.8)	24 (26.1)
Food insecurity (= Secured)[2]	178 (75.1)	154 (74.4)	90 (70.9)	80 (67.8)	61 (66.3)
Wealth tertile ***					
Low	46 (19.4)	70 (33.8)	44 (34.6)	53 (44.9)	36 (39.1)
Mid	85 (35.9)	77 (37.2)	36 (28.3)	38 (32.2)	28 (30.4)
High	106 (44.7)	60 (29.0)	47 (37.0)	27 (22.9)	28 (30.4)

P-value: **P < 0.05, **P < 0.01, ***P < 0.001*

[1] Values are mean (SD) for gestational age, birth weight and maternal age at baseline, and count (%) for the remaining covariates.

[2] Only one category is shown for binary categories, including child sex (female vs. male), maternal ethnicity (Kinh vs. minor ethnicities), maternal education (secondary education or lower vs. vocational training or higher) and food insecurity (insecure vs. secured).

[3] One-way ANOVA and chi-square tests were carried out to assess the differences in the distribution of continuous covariates and categorical covariates, respectively.

Figure 5: Percentage of children consuming individual food groups in the first two years of life by temporal dietary diversity patterns. (Notes: FV - fruits and vegetables).

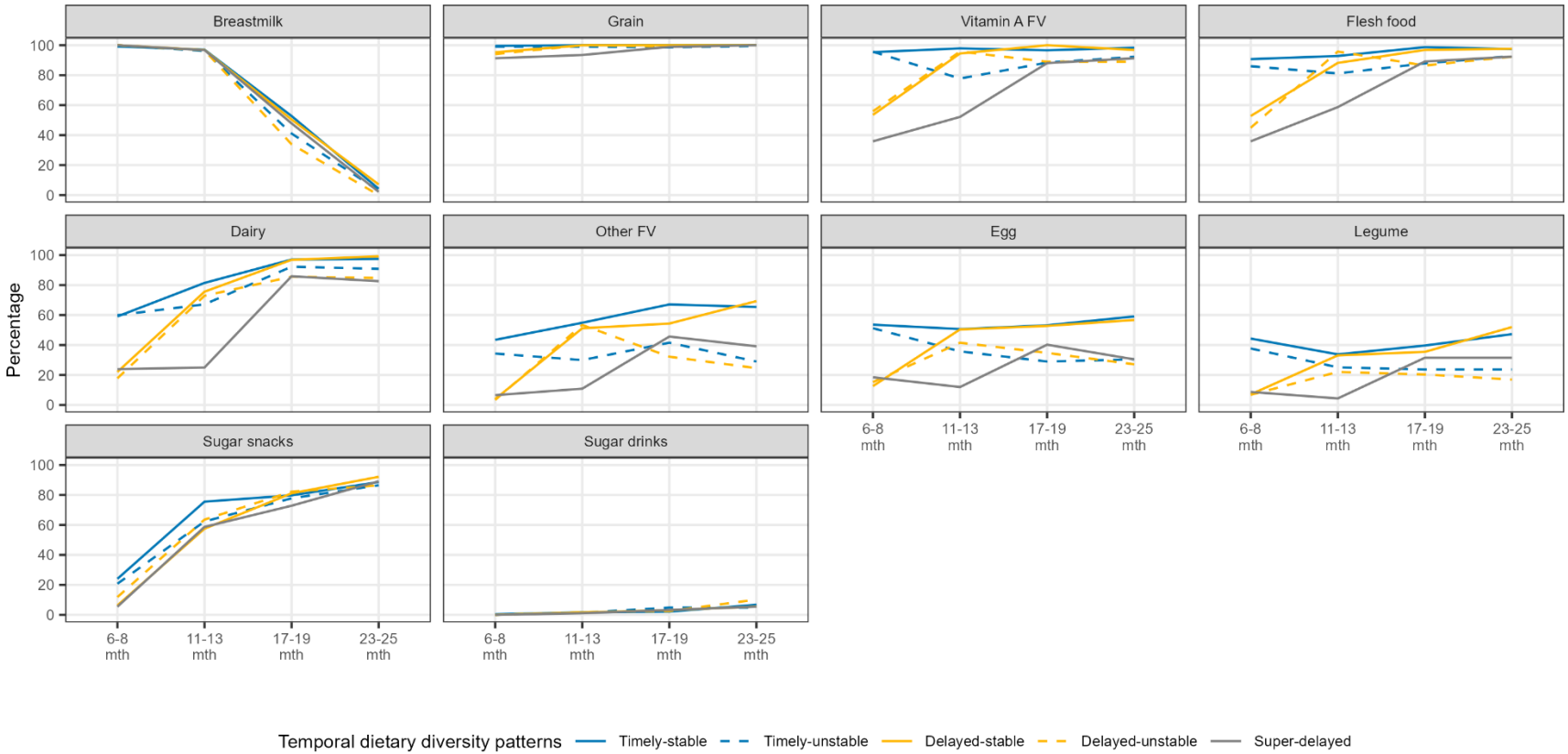

Figure 6: Mean (95% CI) of the conditional growth measures by temporal dietary diversity patterns

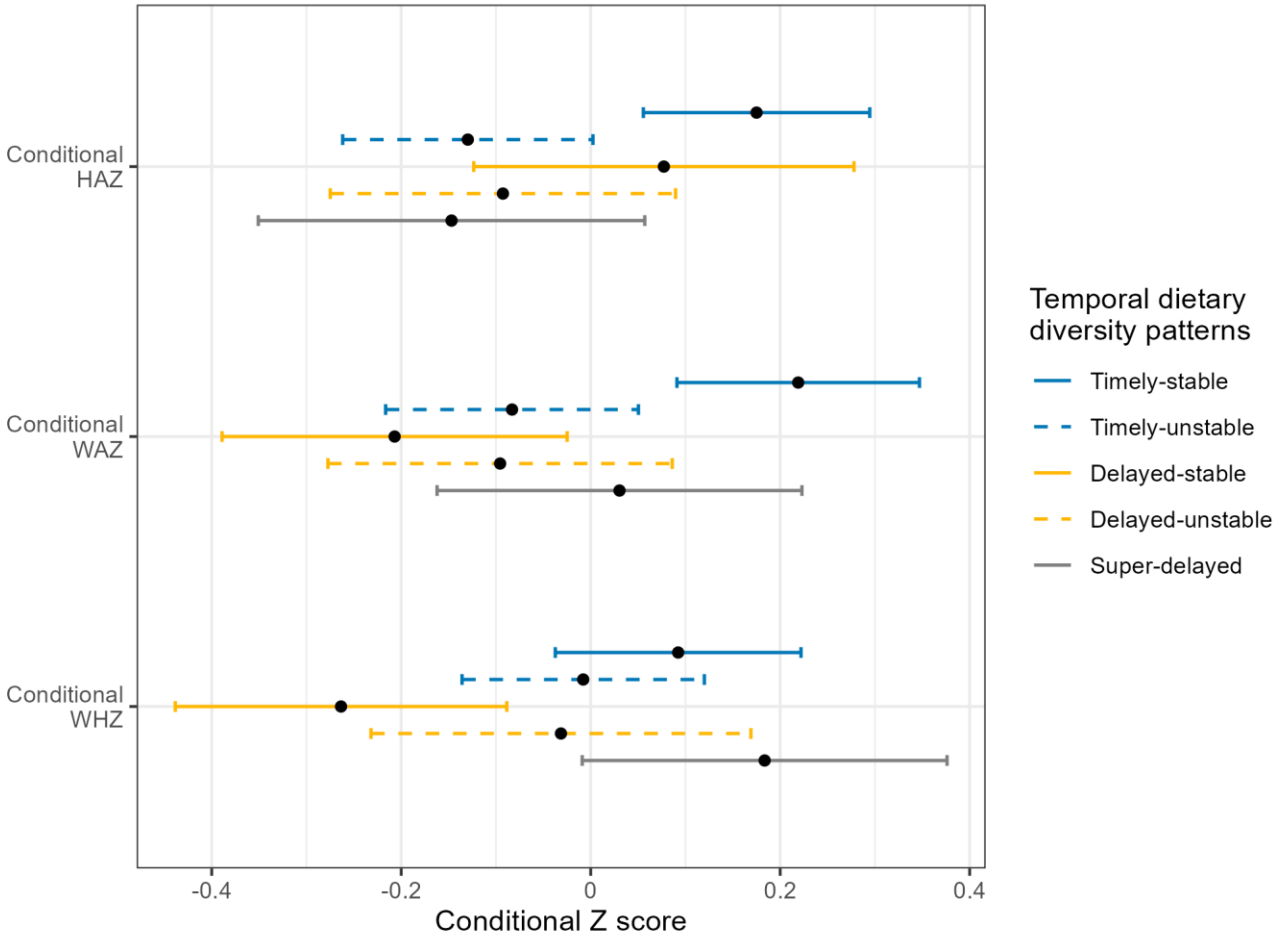

Table 3: Associations of temporal dietary diversity patterns with children's conditional growth between two age windows of 6 – 8 months and 23 – 25 months in rural Vietnam

Temporal dietary diversity patterns (ref: Timely-stable)	Conditional HAZ		Conditional WAZ		Conditional WHZ	
	Unadjusted	Adjusted	Unadjusted		Unadjusted	Adjusted
Timely-unstable	-0.30 (-0.49, -0.12) **	-0.24 (-0.43, -0.06) *	-0.30 (-0.49, -0.12) **	-0.25 (-0.44, -0.07) **	-0.10 (-0.29, 0.09)	-0.07 (-0.26, 0.11)
Delayed-stable	-0.10 (-0.31, 0.12)	-0.02 (-0.23, 0.20)	-0.43 (-0.64, -0.21) ***	-0.35 (-0.56, -0.14) **	-0.36 (-0.57, -0.14) **	-0.29 (-0.51, -0.08) **
Delayed-unstable	-0.27 (-0.49, -0.05) *	-0.16 (-0.39, 0.06)	-0.31 (-0.53, -0.10) **	-0.23 (-0.46, -0.01) *	-0.12 (-0.34, 0.10)	-0.08 (-0.30, 0.15)
Super-delayed	-0.32 (-0.56, -0.08) **	-0.25 (-0.49, -0.02) *	-0.19 (-0.43, 0.05)	-0.13 (-0.37, 0.11)	0.09 (-0.15, 0.33)	0.12 (-0.12, 0.36)

P-value: **P < 0.05, **P < 0.01, ***P < 0.001*

[1] Values are mean difference (95% Confidence interval) which were obtained from unadjusted or adjusted linear regression.

[2] The adjusted models include child sex, gestational age, birth weight, maternal age, maternal ethnicity, maternal education, household wealth, household food security and intervention arms as covariates.

Figure 7: Percentage of children who are stunted, underweight or wasted in the 23 – 25 months of age by temporal dietary diversity patterns

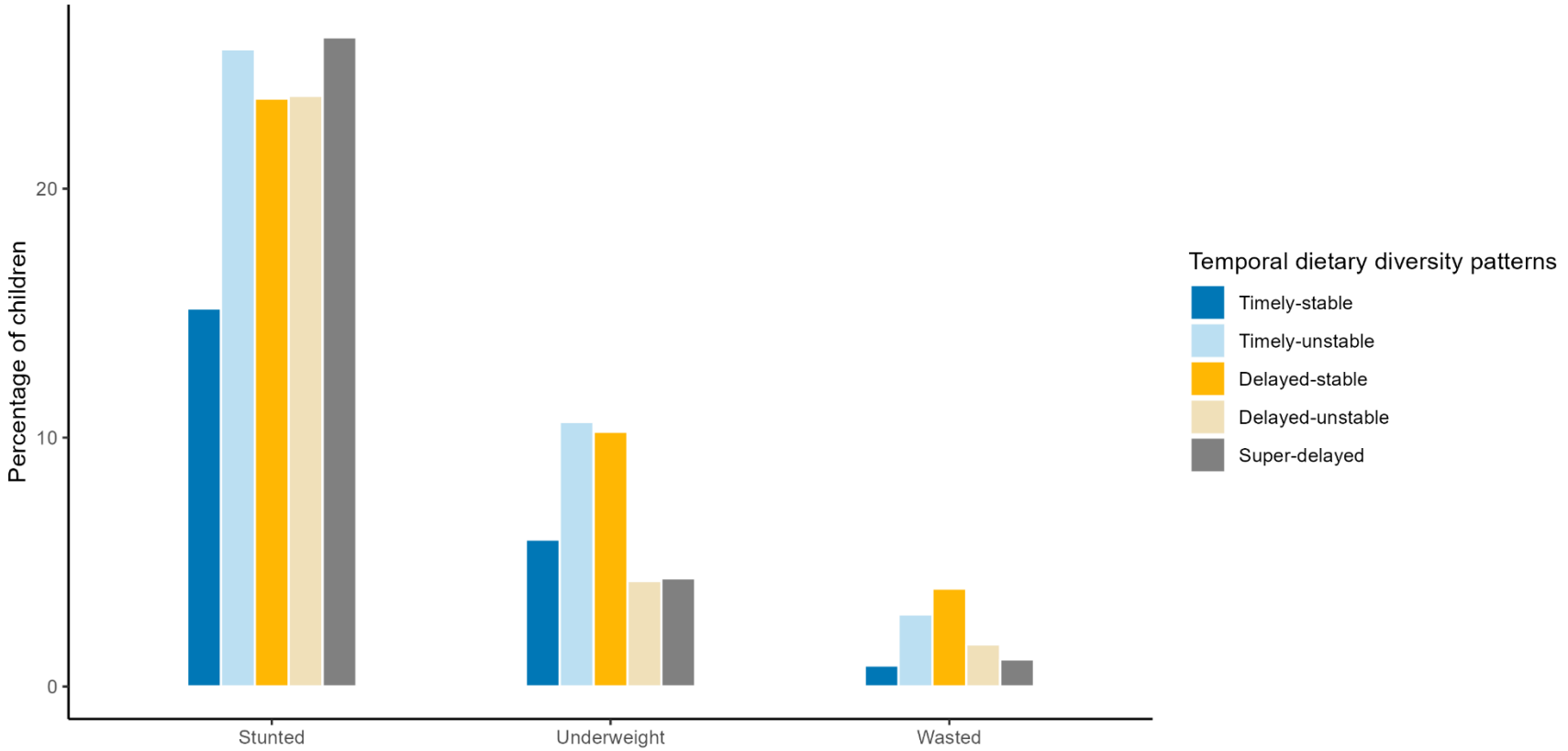

Table 4: Associations of temporal dietary diversity patterns with children's undernutrition outcomes in rural Vietnam

Temporal dietary diversity patterns (ref: Timely-stable)	Stunting		Underweight		Wasting	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Timely-unstable	1.92 (1.20, 3.10) **	1.78 (1.05, 3.04) *	1.89 (0.95, 3.89)	1.04 (0.99, 1.08)	3.51 (0.80, 24.12)	1.02 (1.00, 1.05)
Delayed-stable	1.73 (1.00, 2.97) *	1.23 (0.66, 2.28)	1.82 (0.82, 4.01)	1.02 (0.97, 1.08)	4.82 (1.02, 33.97)	1.03 (1.00, 1.06)
Delayed-unstable	1.74 (0.99, 3.02)	1.53 (0.81, 2.86)	0.70 (0.22, 1.89)	0.97 (0.92, 1.03)	2.03 (0.24, 17.06)	1.02 (0.98, 1.05)
Super-delayed	1.97 (1.09, 3.53) **	1.98 (1.02, 3.80) *	0.72 (0.20, 2.08)	0.98 (0.92, 1.04)	1.29 (0.06, 13.64)	1.00 (0.97, 1.04)

P-value: **P < 0.05, **P < 0.01, ***P < 0.001*

[1] Values are odds ratios (95% Confidence interval) which were obtained from unadjusted or adjusted logistic regression.

[2] The adjusted models include child sex, gestational age, birth weight, maternal age, maternal ethnicity, maternal education, household wealth, household food security and intervention arms as covariates.

Chapter 4: Access to food markets, household wealth and child nutrition in rural Cambodia: findings from nationally representative data

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4.1 Abstract

Access to fresh food markets plays a vital role in household food security and diet quality in transitioning rural economies. However, it is not well understood if market access also improves child nutrition and if the improvement applies to all socioeconomic groups. We combined a national listing of food markets (n=503) with a nationally representative household survey to examine the associations of market access with diet and height across wealth groups in children aged 6 to 23 months in rural Cambodia. Food markets' geographical coordinates were retrieved using Google Maps or estimated using village coordinates publicly available in the Open Development Mekong data platform, and regression calibration was used to calculate household distance to nearest market. Results from the adjusted linear regressions showed that log-transformed distance to nearest markets was associated with child dietary diversity score (β: -0.16; 95% CI: -0.28, -0.05; n = 1537) but not child height-for-age z-score (β: 0.00; 95% CI: -0.12, 0.11; n = 989). Stronger associations between market access and dietary diversity were noted among higher income households but this pattern was non-significant. Children from wealthier household may benefit more from enhanced access to food markets while children from lower-income households may benefit better from programs that diversify food environment to increase their resilience to fluctuations in livelihoods or food prices. Future studies are needed to assess how wealth influences food acquisition and food choice and consequently how it modifies the effects of market access on child nutrition.

4.2 Introduction

Over the past 10 years since the 2013 Lancet Series on Maternal and Child Undernutrition, global policymakers have galvanized efforts to scale up evidence-based interventions for optimal child nutrition (Bhutta et al., 2013; Ruel & Alderman, 2013). Despite these efforts, child undernutrition remains a major challenge (Victora et al., 2021). In low-and-middle-income countries (LMIC), over 60% of the children under-two are given diets lacking nutritious food groups such as eggs, meat, fruits and vegetables (Choudhury et al., 2019) and over 20% experience stunted growth (United Nations Children's Fund (UNICEF), 2021). These troubling statistics reflect the need for new approaches to improve child diet quality and linear growth. While

prior approaches have focused primarily on individual behavioral changes (Dickin et al., 2021; Hossain et al., 2017), nutrition-sensitive agriculture (Masset et al., 2012) and social protection schemes such as cash transfer or food subsidies (Manley et al., 2020), global policymakers have recommended strengthening neighborhood food environment as a novel strategy to improve food access and child nutrition (HLPE, 2017, 2020).

Informal food markets are a key aspect of food environment in rural LMIC, where households are shifting from growing food crops to cash crops and from farm to non-farm activities (Haggblade et al., 2010). Even among subsistence farmers, such as those in Ethiopia and Malawi, over half of the food consumed at home were acquired from markets (Sibhatu et al., 2015). Better access to markets has been theorized to improve household food access and child nutrition through reducing time and cost of food acquisition and increasing household purchasing power via opportunities to acquire modern agricultural inputs and trade goods at the markets (Nandi et al., 2021). Many empirical studies have showed a consistent association of food market access with better household dietary diversity (Headey et al., 2019; Hirvonen et al., 2017; Luckett et al., 2015; Nandi et al., 2021; Sibhatu et al., 2015; Stifel & Minten, 2017). In particular, market access can substitute home food production, as observed in the diminishing effects of home food production on dietary diversity with improving market access (Hirvonen & Hoddinott, 2017; Ludwig, 2018a). These findings together lend support for promoting better road infrastructure and market development to improve household food access and diet quality.

However, whether improving market access has a meaningful benefit on child nutrition remains uncertain. Out of 28 studies in a systematic review of market access and nutrition, only six examined child dietary diversity and anthropometry measures and all the six studies were carried out in remote farming communities in Ethiopia. Of six studies, four showed a positive association between better access to market and child dietary diversity (Headey et al., 2019; Hirvonen & Hoddinott, 2017; Hirvonen et al., 2017; Stifel & Minten, 2017) while other two studies noted a null relationship between market access and child height (Abay & Hirvonen, 2017; Stifel & Minten, 2017). The null association between market access and child height could be due to the high prevalence of stunted growth in rural Ethiopia such that there is little variation in the height

measures to observe the effect of market access. Thus, studies with a wider geographical and socioeconomic heterogeneity are warranted to better examine the role of market access.

Furthermore, hypothesized benefits of food markets on child nutrition might be conditional on household wealth and purchasing power. As households rely more on markets for food, their diets are more sensitive to food price. Nutritious diet costs several times higher than diet that meets calorie requirement (Kachwaha et al., 2020) and fluctuates in price between 30% and 50% by season (Bai et al., 2020), and as a result is unattainable for most of the low-income group (Darmon & Drewnowski, 2015; Raghunathan et al., 2021). It is then possible that households with low purchasing power have to resort to different means of food acquisition even if they live in close proximity to food market. Some households might optimize their spending by purchasing only some specific food from markets. In a study in India, frequency of household visits to markets was associated with household consumption of dairy, nuts and vegetables but not with consumption of other food groups, and these associations were observed only in the highest wealth quintile (Ludwig, 2018b). Another study in Malawi showed that farmers acquired legumes, fruits and vegetables primarily from their own farm production (Jones et al., 2014) and displacing these food crops with cash crops might not yield the income substantial enough to obtain similar dietary diversity with food from markets alone (Shack et al., 1990). More empirical studies are thus needed to investigate how household wealth modifies the effects of market access.

In this present study, we draw nationally representative data from Cambodia to describe its food markets distribution and examine the relationship between market access, household wealth and nutrition in children aged 6 to 23 months in the rural areas. We specifically test two hypotheses: first, better access to market is associated with better child dietary diversity score and height-for-age z-score; and second, the magnitude of these associations is stronger among wealthier households.

4.3 Methods

Study context

Cambodia offers a unique opportunity to assess the role of food markets. In contrast to under-resourced settings where previous studies of food market access were carried out, Cambodia is a fast-growing country with substantial investment in agriculture and rural infrastructure, which allow farmers to take advantage of market opportunities to diversify their production and engage in diverse income-generating activities (Asian Development Bank, 2012). About half of rural labors undertake non-farm activities such as services and manufacturing and many engage in both farm and non-farm activities (National Institute of Statistics et al., 2015). Such rapid rural development has contributed to the significant economic growth and declining poverty and hunger. Despite the socioeconomic development, child undernutrition remains a major public health challenge. In 2015, about one-third of the children under the age of five were stunted and one-half did not meet the minimum dietary diversity score (National Institute of Statistics et al., 2015). Deficiency of key micronutrients such as folate and zinc is also a major concern (National Institute of Statistics et al., 2015).

Informal, open-air food markets is the primary source of fresh food in Cambodia, supplying 90% of the food consumed at an urban home and 50% of food consumed by a rural household (World Food Programme Cambodia, 2010). Food markets are typically organized into tiers, comprising large markets selling diverse fresh food in the provincial and district level and smaller, less diverse markets in the villages. Long distance to markets and high cost of food have been documented as serious concerns for many rural households to access food, despite the presence of mobile food traders selling fresh food in villages lacking food markets (World Food Programme Cambodia, 2010).

Data sources

We obtained child and household data from the Cambodia Demographic and Health Survey 2014 (CDHS) (National Institute of Statistics et al., 2015) and food market data from Cambodia National Animal Health and Production Research Institute. In addition, geographical coordinates of Cambodian villages were obtained from Open Development Mekong, a publicly accessible platform that aggregates and publishes data

on economic and social development in several Southeast Asian countries including Cambodia (Save Cambodia's Wildlife's Atlas Working Group, 2013).

Household survey

CDHS is a geocoded, nationally representative household survey that uses two-stage cluster sampling procedure. In the first stage, a sample of clusters were selected with probability proportional to size within each of the 38 strata, which comprises urban and rural strata of 19 provinces or groups of provinces. In the second stage, a fixed number of households were selected with equal-probability systematic sampling within each cluster. Diet data was collected for the youngest, alive children aged 6 to 23 months, born to women selected for detailed interviews (i.e. de-factor women). Height data was collected for all the children under five years of age, whether or not children were born to de-facto women. We obtained data on child height, child dietary diversity and other sociodemographic information from the child recode file, and data on household ownership of land and livestock from the household recode file.

Households were assigned latitude and longitude coordinates based on the survey clusters, such that all households in the same cluster were assigned the coordinates measured at the center of the cluster. Survey clusters' coordinates were collected using Global Positioning System receivers and were accurate to less than 15 m. Random displacement of survey clusters was introduced to ensure confidentiality with urban clusters displaced within 0 – 2 km and rural clusters within 0 – 5 km, except for 1% of rural clusters displaced up to 10km. Displacement was restricted to ensure that each survey cluster remained within its true district.

Food market data

A census of meat-selling food markets was compiled by NAHPRI in 2019 using data provided by provincial departments of animal health and production, which routinely monitor and manage the safety of food sold in markets. The data included names, administrative locations (village, district and province) and the number of meat vendors of all 503 informal, open-air markets that sell land meat such as poultry, pork or beef. Earlier analyses of Cambodian food markets indicated that, except for some village markets in the remote districts which sell primarily fruits and vegetables, most village, district and provincial markets in Cambodia sold a

wide range of fresh produce including fruits, vegetables, eggs, meat and seafood (World Food Programme Cambodia, 2010). The NAHPRI's listing of meat market was thus deemed a good proxy of all food markets in Cambodia.

Data processing

Household sample selection

Our initial samples included all children aged 6 to 23 months born to de-facto women and living in rural area that had information on either dietary diversity score (n = 1594) or height-for-age z-score (n = 1026). We then randomly selected one child from each household with multiple children to obtain samples that had one child per household. Subsequently, we dropped children with missing data on the covariates. The analytical samples included 1537 children with diet data and 989 children with height data.

Food market geocoding

Food markets were geocoded in two ways. First, markets' names and administrative locations were manually searched in Google Maps to retrieve physical addresses. Google Street View was used to verify that a food market existed at the retrieved physical address. Physical addresses were then converted to geographical coordinates using Google Maps' Place API (Google Maps Platform). Second, if markets were not found in Google Maps, we looked up markets' administrative locations in the Open Development Mekong's village dataset (Save Cambodia's Wildlife's Atlas Working Group, 2013) and substituted markets' coordinates by the coordinates of the village where the market was located. Due to the variation in Latin spellings of administrative divisions in Cambodia (for example, Poi Pet vs. Poipet), we retrieved the most matching village by calculating Levenshtein distance (Black, 2019), a common algorithm used to estimate string similarity. The results were reviewed to verify that the administrative locations were correctly matched. Of 503 markets, 485 markets had coordinates retrieved using Google Maps (n = 95) or substituted by villages (n = 390).

Measures of market density included the count of markets, the count per 10,000 persons and the count per 1000 km^2 for every region and province. Region- and province-specific population data for density measures was obtained from Population Census of Cambodia 2019 (National Institute of Statistics, 2019) while area

data were calculated using Open Development Mekong's Cambodia administrative boundary map (Save Cambodia's Wildlife's Atlas Working Group, 2013). Since measures of market density are used only for describing food market distribution in Cambodia, we did not link market density data with household sample data.

Market proximity was the straight-line distance from each household to its nearest food market. The distance was estimated using the regression calibration approach (Warren et al., 2016) to reduce the impact of CDHS's displacement procedure, which might lead to the mis-identification of nearest markets and the introduction of random error to the distance calculation. In essence, the regression calibration approach involves displacing the coordinates of household survey clusters multiple times using CDHS's displacement procedure to generate a validation dataset. The validation dataset was then used to estimate the variance of the random error and subsequently the expected value of the true distance between households and nearest markets. Market proximity was then used for both description and modeling.

Measurement of key variables

Exposures

Primary exposure was market proximity, which was measured as the straight-line distance from households to their nearest food markets. Distance to markets (km) was specified in the natural log scale to improve model fitting in the presence of outliers and influential points.

Outcomes

Primary outcomes included dietary diversity score and height-for-age z-score and secondary outcomes were the consumption of each of the 11 food groups that make up the dietary diversity score. We derived dietary diversity score from the dietary diversity questionnaire, which consisted of Yes/No questions that asked mothers to recall which of the 11 nutrient-rich food items their child consumed in the last 24 hours. The 11 food items were aggregated to 7 food groups to derive score that ranged from 0 to 7 (WHO et al., 2008). We obtained height-for-age z-score directly from CDHS (National Institute of Statistics et al., 2015), which measured child length/height using standard methods (Cogill, 2003) with the use of collapsible length boards

that was precise to 1mm and converted height into height-for-age z-score according to 2006 WHO child growth standards (World Health Organization, 2016).

Covariates

We included the following socioeconomic characteristics in our analyses: child age and sex, maternal age (15 – 24, 25 – 30, > 30 years), maternal education (no education, incomplete or completed primary education, some secondary education or more), household size (<= 5, > 5 members), household wealth tertile (low, middle, high), agricultural land ownership (<= 1, > 1 hectare), livestock varieties (none, 1 variety, 2 varieties, 3 – 4 varieties), and country region (Tonle Sap Lake, Plain, Coastal, and Plateau regions). Maternal age and maternal education were categorized to capture non-linearity of their relationships with child nutrition indicators (Alderman & Headey, 2014; Fall et al., 2015) while household size and household wealth were categorized to minimize the influence of outliers and influential. We dichotomized agricultural land size at 1 hectare to obtain a proxy of food security based on an earlier finding that 1 hectare of land was a threshold to meet the milled rice requirement of a family of five in Cambodia (World Food Programme, 2008). Livestock varieties was calculated using questions on the number of chickens, pigs, cows, buffalo, horses or sheep that households owned.

Statistical strategies

We first described the characteristics of children included in the analysis using mean and standard deviation for continuous variables and percentages for categorical variables. Unadjusted and adjusted linear regressions were carried out to examine the associations of natural log-transformed distance to nearest markets with child nutrition outcomes. Both the exposure and outcomes were specified in continuous scale. In the adjusted models, we decided a priori to adjust for sex, child age, maternal age, maternal education, household size, household wealth, ownership of agricultural land, ownership of livestock and country region. Multiple collinearity was assessed in all models. Variance inflation factors >2 were considered an indication of high collinearity (9).

We further examined the evidence of effect modification by household wealth by introducing an interaction term to the adjusted models of dietary diversity score and height-for-age z-score. We calculated the slope of distance to markets on dietary diversity for each level of household wealth using post-hoc estimations and obtained the overall P-value of the interaction term from the Type 3 test.

Lastly, we explored which of the 11 food groups included in the calculation of dietary diversity score might be related to distance to markets. We visualized food group consumption by deciles of distance and estimated the unadjusted and adjusted associations between log-transformed distance to market and food group consumption using linear probability model. Only food groups that were statistically significant in the unadjusted model were kept in the adjusted models, which were corrected for multiple comparisons using Bonferroni, Holm and Benjamini Hochberg method. We chose linear probability instead of the conventional logistic regression approach for better interpretation and on the basis that food consumption in our study varied within 20% to 80%, a range where linear probability model yields similar estimates to other non-linear models (Hellevik, 2009).

All analyses were conducted in R statistical software version 4.1.2 and accounted for the complex survey design (R Development Core Team, 2010), and P-values < 0.05 were considered statistically significant.

4.4 Results

Food market distribution in Cambodia

Food markets were distributed unevenly in Cambodia (Figure 1A). Markets were highly concentrated in the plain areas, typically in the center of the Mekong Lowlands or along the Tonle Sap Lake. These markets also had large number of meat markets. In contrast, markets were sparse and small in size in areas with high relief such as the Plateau region. On average, Mekong Lowlands region (9/1000 km^2) had 3.6 times higher number of markets per areal unit than Tonle Sap Lake region (2.5/1000 km^2) and 18 times higher than the Northeastern Plateau region (0.5/1000 km^2) (Supplementary table 1).

Nevertheless, food market distribution closely follows population distribution (Figure 1B). Market density by population varied slightly between 2.5 to 3.5 per 100,000 persons across the four regions and between 1 to 7 per 100,000 persons across provinces (Supplementary table 1).

Average distance to nearest markets also differed across regions (Figure 1). On average, rural households in the Mekong Lowlands, Tonle Sap Lake and Southern Coast regions had to travel between 6 and 7 km (SD ranges between 4.6 and 6.5 km) to reach their nearest markets while households in Northeastern Plateau had to commune approximately 12 km (SD: 9.6 km) to get to their nearest markets (Figure 2).

Children characteristics

In the sample of children with dietary diversity data (n = 1537), mean dietary diversity score was 3.20 (SD: 1.62) while mean distance to nearest markets was 7.22 (5.98) km. Half of the children were male and mean child age was 14.35 (5.31) month. About 14% of the mothers had no education, 50% had incomplete or completed primary education and 30% had secondary education or higher. Three-quarters of the households owned less than 1 hectare of agricultural land and one-quarter did not own any livestock. In the sample of children with height data (n = 989), mean height-for-age z-score was -1.26 (1.31) and other covariates had similar covariate distribution as the sample of children with dietary diversity data (Table 1).

Associations between distance to markets and child nutrition indicators

Distance to nearest markets was inversely associated with child dietary diversity score (β: -0.16; 95% CI: -0.28, -0.05) (Table 2). Being older in age and born in a higher wealth household were also associated with better dietary diversity. However, distance to nearest markets was not associated with height-for-age z-score (β: 0.00; 95% CI: -0.12, 0.11). Rather, child age, household wealth and geographical region were significant predictors. In all adjusted models, VIFs were below 2, suggesting that multicollinearity was not present.

Effect modifications of market access with child diet by household wealth

Analyses evaluating effect modification were carried out for dietary diversity score, the only outcome for which we observed a main effect. Our result showed a non-significant trend of stronger associations from low to middle and to high wealth tertile (Figure 3). In addition, the association between distance to nearest

markets and dietary diversity is significant in the high wealth tertile but non-significant in low and middle wealth tertiles.

Food consumptions by wealth and distance to markets

Overall, among animal-sourced foods, consumption of fish and seafood was relatively high (50% to 60%) but consumption of land meat was modest (40% - 50%) and of egg and dairy was low (15% – 30%). Regarding fruits and vegetables, only consumption of leafy vegetables was high (50%) while consumption of vitamin A-rich fruits and vegetables or other fruits and vegetables were all low (10 – 30%). Grain was a universal food group but nuts and legumes were rarely consumed (Supplementary figure 1).

Consumption of land meat, egg, non-vitamin A fruits and vegetables, dairy and nuts were progressively higher with higher wealth tertile. In contrast, consumption of fish and seafood was lower with higher wealth tertile and consumption of leafy vegetable and vitamin A vegetables do not seem to differ linearly with wealth tertiles (Supplementary figure 1).

Similarly, consumption of land meat, egg, dairy and other fruits and vegetables increased with lower decile of distance to market while consumption of other food groups did not seem to change linearly with distance to market (Supplementary figure 2). The unadjusted regression model also indicated that only consumption of land meat, egg, dairy and other fruits and vegetables were associated with log-transformed distance to the nearest market. We thus run the adjusted model only for these four food groups accounting for covariates indicated in the Table 2. Only associations of distance to markets with consumption of land meat and other fruits and vegetables remained significant in the adjusted model. These results were unchanged after correcting for multiple comparisons using Bonferroni, Holm or Benjamini Hochberg methods (Supplementary table 2).

4.5 Discussion

We leverage a national census of food markets in Cambodia to assess the relationship between proximity to food markets and child nutrition indicators. In this context, we observe a highly uneven distribution of food markets with large markets concentrating in the populated areas in the low lands and small markets sparsely

distributed in the remote, plateau areas. We find that proximity to food markets is associated with better child dietary diversity but not child height among young children in the rural Cambodia. The association between market proximity and dietary diversity was stronger for children residing in the wealthier households but this effect modification was non-significant.

Child diet and market access

We find that children who lived closer to markets had better dietary diversity than children who lived farther. This finding is consistent with previous research, which show better child's dietary diversity with shorter distance to market (Abay & Hirvonen, 2017), shorter time travelled to market (Headey et al., 2019), lower transportation cost to markets (Hirvonen et al., 2017; Stifel & Minten, 2017) or better food variety sold in nearest markets (Headey et al., 2019). However, the magnitude of these associations tends to be small. For example, in Ethiopia, child dietary diversity score during the lean season differed by 0.73 between households living within 3km and households living further than 3km from nearest markets (Abay & Hirvonen, 2017). Another study in Ethiopia indicates that, after controlling for distance to markets, increasing the number of food groups sold in the market from three to six was associated with a small increase of 0.27 in the number of foods consumed by the children (Headey et al., 2019). In our study, the magnitude of the association is also small, such that increasing the distance by 10% is associated with a 0.016 lower dietary diversity score.

One possible reason for the weak relationship between market proximity and child diet is that mobile traders selling meat and fresh produce in the back their motorcycles are common in rural villages where food markets are not available in close proximity or where food markets carry a limited range of fresh food items (World Food Programme Cambodia, 2010). To certain extent, these mobile traders may be able to compensate the lack of physical access to a food market. Mobile food vendors seem to offer a flexible mechanism to transport fresh food to needing communities, but how they work and what is their role on household food access needs to be quantitatively assessed and understood.

The weak association between diet and market proximity might also be explained by the differential effects of market access across socioeconomic groups. In our study, we find that the associations are strong and

significant for children from the high wealth tertile and weak and non-significant for the middle and low wealth tertiles. Although the overall effect modification by wealth is non-significant, it could be due to the lack of statistical power and the use of asset-based wealth index, which has been showed to misclassify households into wealth categories (Balen et al., 2010; Foreit & Schreiner, 2011; Houweling et al., 2003). Two reasons might explain why wealthier children benefit more from market access than children from lower income households. First, households from lower wealth tertiles may not afford to purchase fresh food from markets, which costs several times higher than staple food (Kachwaha et al., 2020; Raghunathan et al., 2021) and often fluctuate in price during food crises (Bai et al., 2020). Second, households from lower wealth tertiles might rely on other means of food acquisition and thus are less dependent on markets for food access. For example, given that capturing wild fish is a common practice in Cambodia (Freed et al., 2020), lower and middle wealth tertiles may engage in this practice more frequently than high wealth tertile group, explaining the higher consumption of fish and seafood among children from the lower wealth tertiles in our study. Low and middle wealth tertiles also have a higher share of households who owe agricultural land or livestocks than the high wealth tertile (result not shown), which can be the source of egg, meat, fruits and vegetables.

The weak association between child diet and market proximity may also be due to barriers to optimal child feeding. These barriers might happen in both food secured and food insecure families, which explains why the gain in dietary diversity associated with better market access is smaller in children than in adults (Stifel & Minten, 2017). Several studies of food secured, relatively well-off households have suggested that caregivers might not aware of the importance of nutritious food (Sirasa et al., 2020) or do not know how to manage children's food refusal and pickiness behaviors (Gebru et al., 2021; Sirasa et al., 2020). In this study, we cannot test the effect modification of market access and child dietary diversity by feeding practices due to lack of data on this domain, but a previous study showed that improvement in child diet associated with market access was larger in households with better maternal nutritional knowledge (Hirvonen et al., 2017). Future work of market access and child diet should investigate the effect modification of market access and child diet by child feeding practices.

Child height and market access

In this present study, child height-for-age z-score is not related to proximity to nearest market. Out of 28 studies listed a recent systematic review of market access and nutrition, two studies have also noted a null association between distance to nearest markets and child height (Abay & Hirvonen, 2017; Stifel & Minten, 2017). On the one hand, it is possible that the effects of market access on dietary diversity is not large enough to lead to significant improvement in height. On the other hand, the null association might be due to the limitation of the study design and the choice of indicators. It is widely known that linear growth is influenced by not only early life's diet quality but also intra-uterine exposures and growth (Schaible & Kaufmann, 2007). Thus, one pathway that market access can contribute to better child nutrition is through improving maternal diet and intra-uterine development. Furthermore, other indicators of child nutrition such as micronutrient status are more sensitive to changes in diet and to mothers' nutritional status (Hedrick et al., 2012), and thus might be more strongly predicted by market access. Thus, a longitudinal study with data on micronutrient biomarkers are needed to capture the total effects of market access on different indicators of child nutrition and examine how these total effects are mediated by maternal diet during pregnancy versus child diet in the early childhood.

Policy implications

Our study also reveals an uneven distribution of food markets across geographical regions. This pattern, together with the finding of small benefits of market access on child diet and concern of unaffordability of nutritious food, suggests the need for tailored programs and policies to improve food access. In areas with large population, where large-sized food markets were concentrated, deliberate socio-economic policies are needed to support the informal food markets. Discussions on informal food markets have primarily centered around urban food security and nutrition (Giroux et al., 2021; Tacoli, 2016), but the dialogue should be inclusive of rural dwellers by recognizing their reliance on food markets especially in the transitioning rural economies. The policies may take the form of subsidy schemes to establish new markets, incentivize farmers or traders to sell diverse food groups and support vendors with facilities for food storage and preparation (Scott, 2007).

In contrast, sparsely populated areas are typically poorer and live a longer distance from food markets. As showed in our study, children from poorer households do not gain as much benefit from access to market as children from wealthier households. Furthermore, households in these areas might be disproportionately affected when food system is disrupted, such as during lean seasons and times of lost crops (Bonuedi et al., 2021) or pandemics such as COVID-19 pandemic (Ghosh-Jerath et al., 2022; Harris et al., 2020), the latter impeded food supply chain due to restricted movements of goods and people. During these times, low-income households may turn to food produced at home (Ghosh-Jerath et al., 2022; Harris et al., 2020; Kachwaha et al., 2020), food shared by other members of the community (Nosratabadi et al., 2020) or readily available wild food in the natural environment (Ghosh-Jerath et al., 2022; Hickey et al., 2016). These findings stress the importance of a diverse, flexible and resilient food environment in buffering the impact of potential disruptions on the low-income in the rural. In Cambodia specifically, ongoing programs and policies to provide safety net (Culas & Tek, 2016), promote home gardens (Depenbusch et al., 2022) and conserve rice field ecosystem for wild fisheries (Fisheries Administration, 2011) should be prioritized in areas that lacked food markets and coupled with initiatives to strengthen mobile food traders.

Strengths and limitations

The strength of this study lies in its coverage of large geographical regions and socioeconomic groups in Cambodia, which was enabled by the use of unique national census of meat-selling food markets and novel approach to geocode food markets using Google Maps. Food markets geocoding remains an under-utilized tool in food access research but it is a promising approach because it saves the cost of conducting field work and market survey. In our study, we managed to geocode 485 out of 505 markets (96%), suggesting that this approach is promising and capable in characterizing the neighborhood food access. Furthermore, we used the novel technique of regression calibration to account for the random displacement of geographical coordinates of the household clusters in CDHS, a procedure meant to ensure confidentiality of CDHS's respondents. Few studies have adequately accounted for this displacement procedure, which are likely lead to bias towards the null in the regression estimates (Warren et al., 2016). Regression calibration, on the other hand, has been demonstrated to generate unbiased estimates (Warren et al., 2016).

The study is not without limitations. First, it is cross-sectional in design and thus we are unable to conclude the causality of the effects of market access measures and child nutrition indicators. Second, we obtain food market data from a census of meat-selling food markets and lack data on markets that sell only fruits and vegetables. Nevertheless, an earlier report of food markets in 2010 in Cambodia observed that the large majority of food markets in Cambodia sold a wide range of meat, fruits and vegetables, suggesting that meat-selling markets can be a good proxy of food markets (World Food Programme Cambodia, 2010). Third, the food market listing was compiled in 2019 while our household survey was carried out in 2015, and within these four year there might be newly formed markets or markets that were closed down. However, food markets in Cambodia are well-structured across the administrative tiers, including village, commune, district and province (World Food Programme Cambodia, 2010), and therefore should be relatively stable. Thus, we deem that there were minimal changes to the food markets over the four-year period. Lastly, we lack important information on which food, how much and at which cost households purchase from food markets versus other sources, which reduces our power to identify the causal relationship linking market access and child nutrition. Future studies should incorporate these measures to strengthen the study design.

4.6 Conclusions

In conclusion, our study reveals that living close to food markets is associated with children's diverse diet with a small effect size. Furthermore, there might be heterogeneity in the benefits of food markets on improving diet across different income groups with larger benefits seen in wealthier children. These results suggest cautious optimism about the benefits of food markets on child nutrition and support a tailored approach in promoting neighborhood access, which involves strengthening informal food markets in densely populated areas where food market presence is strong and diversifying sources of food acquisitions including home gardens and mobile vendors in sparsely population areas with low presence of food markets. Future research should incorporate other measures of nutrition such as micronutrient biomarkers and include data on household food acquisition to better understand the role of market access on child nutrition across socioeconomic groups.

4.7 References

Abay, K., & Hirvonen, K. (2017). Does Market Access Mitigate the Impact of Seasonality on Child Growth? Panel Data Evidence from Northern Ethiopia. *The Journal of Development Studies*, *53*(9), 1414-1429. https://doi.org/https://doi.org/10.1080/00220388.2016.1251586

Alderman, H., & Headey, D. D. (2014). The Nutritional Returns to Parental Education. *IFPRI Discussion Paper, Available at SSRN*. https://doi.org/http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/128434

Asian Development Bank. (2012). *Rural Development for Cambodia: Key Issues and Constraints*.

Bai, Y., Naumova, E. N., & Masters, W. A. (2020). Seasonality of diet costs reveals food system performance in East Africa. *Science Advances*, *6*(49), eabc2162. https://doi.org/https://doi.org/10.1126/sciadv.abc2162

Balen, J., McManus, D. P., Li, Y.-S., Zhao, Z.-Y., Yuan, L.-P., Utzinger, J., Williams, G. M., Li, Y., Ren, M.-Y., Liu, Z.-C., Zhou, J., & Raso, G. (2010). Comparison of two approaches for measuring household wealth via an asset-based index in rural and peri-urban settings of Hunan province, China. *Emerging Themes in Epidemiology*, *7*(1), 7. https://doi.org/https://doi.org/10.1186/1742-7622-7-7

Bhutta, Z. A., Das, J. K., Rizvi, A., Gaffey, M. F., Walker, N., Horton, S., Webb, P., Lartey, A., & Black, R. E. (2013). Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *The Lancet*, *382*(9890), 452-477. https://doi.org/https://doi.org/10.1016/S0140-6736(13)60996-4

Black, P. E. (2019). *"Levenshtein distance" in "National Institute of Standards and Technology"*. https://www.nist.gov/dads/HTML/Levenshtein.html

Bonuedi, I., Kornher, L., & Gerber, N. (2021). Agricultural seasonality, market access, and food security in Sierra Leone. *Food Security*. https://doi.org/https://doi.org/10.1007/s12571-021-01242-z

Choudhury, S., Headey, D. D., & Masters, W. A. (2019). First foods: Diet quality among infants aged 6-23 months in 42 countries. *Food Policy*, *88*, Article Unsp 101762. https://doi.org/https://doi.org/10.1016/j.foodpol.2019.101762

Cogill, B. (2003). *Anthropometric indicators measurement guide: Food and Nutrition Technical Assistance Project*.

Culas, R. J., & Tek, K. (2016). Food security in Cambodia: trends and policy objectives. *International Journal of Development Issues*, *15*(3), 306-327. https://doi.org/https://doi.org/10.1108/IJDI-06-2016-0033

Darmon, N., & Drewnowski, A. (2015). Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: a systematic review and analysis. *Nutrition Reviews*, *73*(10), 643-660. https://doi.org/https://doi.org/10.1093/nutrit/nuv027

Depenbusch, L., Schreinemachers, P., Brown, S., & Roothaert, R. (2022). Impact and distributional effects of a home garden and nutrition intervention in Cambodia. *Food Security*. https://doi.org/https://doi.org/10.1007/s12571-021-01235-y

Dickin, K. L., Litvin, K., McCann, J. K., & Coleman, F. M. (2021). Exploring the Influence of Social Norms on Complementary Feeding: A Scoping Review of Observational, Intervention, and Effectiveness Studies. *Current developments in nutrition*, *5*(2). https://doi.org/https://doi.org/10.1093/cdn/nzab001

Fall, C. H., Sachdev, H. S., Osmond, C., Restrepo-Mendez, M. C., Victora, C., Martorell, R., Stein, A. D., Sinha, S., Tandon, N., Adair, L., Bas, I., Norris, S., & Richter, L. M. (2015). Association between maternal age at childbirth and child and adult outcomes in the offspring: a prospective study in five low-income and middle-income countries (COHORTS collaboration). *Lancet Global Health*, *3*(7), e366-377. https://doi.org/https://doi.org/10.1016/s2214-109x(15)00038-8

Fisheries Administration. (2011). *Cambodia Strategic Planning Framework for Fisheries 2010–2019*

Foreit, K. G. F., & Schreiner, M. (2011). *Comparing Alternative Measures of Poverty: Assets-Based Wealth Index vs. Expenditures-Based Poverty Score* (MEASURE Evaluation PRH, Issue.

Freed, S., Kura, Y., Sean, V., Mith, S., Cohen, P., Kim, M., Thay, S., & Chhy, S. (2020). Rice field fisheries: Wild aquatic species diversity, food provision services and contribution to inland fisheries. *Fisheries Research*, *229*, 105615. https://doi.org/https://doi.org/10.1016/j.fishres.2020.105615

Gebru, N. W., Gebreyesus, S. H., Yirgu, R., Habtemariam, E., & Abebe, D. S. (2021). The relationship between caregivers' feeding practices and children's eating behaviours among preschool children in Ethiopia. *Appetite*, *157*, 104992. https://doi.org/https://doi.org/10.1016/j.appet.2020.104992

Ghosh-Jerath, S., Kapoor, R., Dhasmana, A., Singh, A., Downs, S., & Ahmed, S. (2022). Effect of COVID-19 Pandemic on Food Systems and Determinants of Resilience in Indigenous Communities of Jharkhand State, India: A Serial Cross-Sectional Study [Original Research]. *Frontiers in Sustainable Food Systems*, *6*. https://doi.org/https://doi.org/10.3389/fsufs.2022.724321

Giroux, S., Blekking, J., Waldman, K., Resnick, D., & Fobi, D. (2021). Informal vendors and food systems planning in an emerging African city. *Food Policy*, *103*, 101997. https://doi.org/https://doi.org/10.1016/j.foodpol.2020.101997

Google Maps Platform. *Google Places API*. . Retrieved November 17 from https://developers.google.com/places/web-service/overview

Haggblade, S., Hazell, P., & Reardon, T. (2010). The Rural Non-farm Economy: Prospects for Growth and Poverty Reduction. *World Development*, *38*(10), 1429-1441. https://doi.org/https://doi.org/10.1016/j.worlddev.2009.06.008

Harris, J., Depenbusch, L., Pal, A. A., Nair, R. M., & Ramasamy, S. (2020). Food system disruption: initial livelihood and dietary effects of COVID-19 on vegetable producers in India. *Food Security*, *12*(4), 841-851. https://doi.org/https://doi.org/10.1007/s12571-020-01064-5

Headey, D., Hirvonen, K., Hoddinott, J., & Stifel, D. (2019). Rural Food Markets and Child Nutrition. *American Journal of Agricultural Economics*, *101*, 1311-1327. https://doi.org/https://doi.org/10.1093/ajae/aaz032

Hedrick, V. E., Dietrich, A. M., Estabrooks, P. A., Savla, J., Serrano, E., & Davy, B. M. (2012). Dietary biomarkers: advances, limitations and future directions. *Nutrition Journal*, *11*(1), 109. https://doi.org/https://doi.org/10.1186/1475-2891-11-109

Hellevik, O. (2009). Linear versus logistic regression when the dependent variable is a dichotomy. *Quality & Quantity*, *43*(1), 59-74. https://doi.org/https://doi.org/10.1007/s11135-007-9077-3

Hickey, G. M., Pouliot, M., Smith-Hall, C., Wunder, S., & Nielsen, M. R. (2016). Quantifying the economic contribution of wild food harvests to rural livelihoods: A global-comparative analysis. *Food Policy*, *62*, 122-132. https://doi.org/https://doi.org/10.1016/j.foodpol.2016.06.001

Hirvonen, K., & Hoddinott, J. (2017). Agricultural production and children's diets: evidence from rural Ethiopia [https://doi.org/10.1111/agec.12348]. *Agricultural Economics*, *48*(4), 469-480. https://doi.org/https://doi.org/10.1111/agec.12348

Hirvonen, K., Hoddinott, J., Minten, B., & Stifel, D. (2017). Children's Diets, Nutrition Knowledge, and Access to Markets. *World Development*, *95*, 303-315. https://doi.org/https://doi.org/10.1016/j.worlddev.2017.02.031

HLPE. (2017). *Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.*

HLPE. (2020). *Food security and nutrition: Building a global narrative towards 2030* (A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Issue.

Hossain, M., Choudhury, N., Adib Binte Abdullah, K., Mondal, P., Jackson, A. A., Walson, J., & Ahmed, T. (2017). Evidence-based approaches to childhood stunting in low and middle income countries: a systematic review. *Archives of Disease in Childhood*, *102*(10), 903-909. https://doi.org/https://doi.org/10.1136/archdischild-2016-311050

Houweling, T. A. J., Kunst, A. E., & Mackenbach, J. P. (2003). Measuring health inequality among children in developing countries: does the choice of the indicator of economic status matter? *International Journal for Equity in Health*, *2*(1), 8. https://doi.org/https://doi.org/10.1186/1475-9276-2-8

Jones, A., Shrinivas, A., & Kerr, R. (2014). Farm Production Diversity Is Associated with Greater Household Dietary Diversity in Malawi: Findings from Nationally Representative Data. *Food Policy*, *46*, 1–12. https://doi.org/https://doi.org/10.1016/j.foodpol.2014.02.001

Kachwaha, S., Nguyen, P. H., DeFreese, M., Avula, R., Cyriac, S., Girard, A., & Menon, P. (2020). Assessing the Economic Feasibility of Assuring Nutritionally Adequate Diets for Vulnerable Populations in Uttar Pradesh, India: Findings from a "Cost of the Diet" Analysis. *Current developments in nutrition*, *4*(12), nzaa169-nzaa169. https://doi.org/https://doi.org/10.1093/cdn/nzaa169

Luckett, B. G., DeClerck, F. A. J., Fanzo, J., Mundorf, A. R., & Rose, D. (2015). Application of the Nutrition Functional Diversity indicator to assess food system contributions to dietary diversity and sustainable diets of Malawian households. *Public Health Nutrition*, *18*(13), 2479-2487. https://doi.org/https://doi.org/10.1017/S136898001500169X

Ludwig, T. (2018a). *An Egg for an Egg and a Bean for a Bean? How Production Diversity Determines Dietary Diversity of Smallholder Farmers in Rural India* (ZEF - Discussion Papers on Development Policy No. 247, Issue.

Ludwig, T. (2018b). *An Egg for an Egg and a Bean for a Bean? How Production Diversity Determines Dietary Diversity of Smallholder Farmers in Rural India.* (Discussion Papers on Development Policy No. 247, Issue.

Manley, J., Balarajan, Y., Malm, S., Harman, L., Owens, J., Murthy, S., Stewart, D., Winder-Rossi, N. E., & Khurshid, A. (2020). Cash transfers and child nutritional outcomes: a systematic review and meta-analysis. *BMJ Global Health*, *5*(12), e003621. https://doi.org/https://doi.org/10.1136/bmjgh-2020-003621

Masset, E., Haddad, L., Cornelius, A., & Isaza-Castro, J. (2012). Effectiveness of agricultural interventions that aim to improve nutritional status of children: systematic review. *BMJ*, *344*, d8222. https://doi.org/https://doi.org/10.1136/bmj.d8222

Nandi, R., Nedumaran, S., & Ravula, P. (2021). The interplay between food market access and farm household dietary diversity in low and middle income countries: A systematic review of literature. *Global Food Security*, *28*, 100484. https://doi.org/https://doi.org/10.1016/j.gfs.2020.100484

National Institute of Statistics. (2019). *General Population Census of the Kingdom of Cambodia 2019: Provisional Population Totals*.

National Institute of Statistics, Directorate General for Health, & ICF International. (2015). *Cambodia Demographic and Health Survey 2014*.

Nosratabadi, S., Khazami, N., Abdallah, M. B., Lackner, Z., S Band, S., Mosavi, A., & Mako, C. (2020). Social Capital Contributions to Food Security: A Comprehensive Literature Review. *Foods (Basel, Switzerland)*, *9*(11), 1650. https://doi.org/https://doi.org/10.3390/foods9111650

R Development Core Team. (2010). *R: A language and environment for statistical computing*. In R Foundation for Statistical Computing. http://www.R-project.org

Raghunathan, K., Headey, D., & Herforth, A. (2021). Affordability of nutritious diets in rural India. *Food Policy*, *99*, 101982. https://doi.org/https://doi.org/10.1016/j.foodpol.2020.101982

Ruel, M. T., & Alderman, H. (2013). Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? *The Lancet*, *382*(9891), 536-551. https://doi.org/https://doi.org/10.1016/S0140-6736(13)60843-0

Save Cambodia's Wildlife's Atlas Working Group. (2013). *Village distance to upper secondary schools in Cambodia (2013)* Open Development Cambodia. https://data.opendevelopmentcambodia.net/en/dataset/map_distance_to_upper_secondary_schools?type=dataset

Schaible, U. E., & Kaufmann, S. H. E. (2007). Malnutrition and Infection: Complex Mechanisms and Global Impacts. *PLOS Medicine*, *4*(5), e115. https://doi.org/10.1371/journal.pmed.0040115

Scott, S. (2007). *Promises and challenges of the informal food sector in developing countries*. http://www.fao.org/tempref/docrep/fao/010/a1124e/a1124e00.pdf

Shack, K. W., Grivetti, L. E., & Dewey, K. G. (1990). Cash cropping, subsistence agriculture, and nutritional status among mothers and children in lowland Papua New Guinea. *Social Science & Medicine*, *31*(1), 61-68. https://doi.org/https://doi.org/10.1016/0277-9536(90)90010-p

Sibhatu, K. T., Krishna, V. V., & Qaim, M. (2015). Production diversity and dietary diversity in smallholder farm households. *Proceedings of the National Academy of Sciences*, *112*(34), 10657-10662. https://doi.org/https://doi.org/10.1073/pnas.1510982112

Sirasa, F., Mitchell, L., Silva, R., & Harris, N. (2020). Factors influencing the food choices of urban Sri Lankan preschool children: Focus groups with parents and caregivers. *Appetite*, *150*, 104649. https://doi.org/https://doi.org/10.1016/j.appet.2020.104649

Stifel, D., & Minten, B. (2017). Market Access, Well-being, and Nutrition: Evidence from Ethiopia. *World Development*, *90*, 229-241. https://doi.org/http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129406

Tacoli, C. (2016). *Informal food systems and food security in rural and urban East Africa.* http://pubs.iied.org/17336IIED.html?c=urban

United Nations Children's Fund (UNICEF). (2021). *Fed to Fail? The Crisis of Children's Diets in Early Life* (2021 Child Nutrition Report, Issue.

Victora, C. G., Christian, P., Vidaletti, L. P., Gatica-Domínguez, G., Menon, P., & Black, R. E. (2021). Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda. *The Lancet*, *397*(10282), 1388-1399. https://doi.org/https://doi.org/10.1016/S0140-6736(21)00394-9

Warren, J. L., Perez-Heydrich, C., Burgert, C. R., & Emch, M. E. (2016). Influence of Demographic and Health Survey Point Displacements on Distance-Based Analyses. *Spatial Demography*, *4*(2), 155-173. https://doi.org/https://doi.org/10.1007/s40980-015-0014-0

WHO, UNICEFF, IFPRI, UC Davis, & FANTA. (2008). *Macro International. Indicators for assessing infant and young child feeding practices*.

World Food Programme. (2008). *Comprehensive Food Security & Vulnerability Analysis*.

World Food Programme Cambodia. (2010). *Cambodia Food Market Analysis and Survey Report*. https://documents.wfp.org/stellent/groups/public/documents/ena/wfp244779.pdf

World Health Organization. (2016). *WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development*. http://www.who.int/childgrowth/standards/en/

4.8 Figures & tables

Figure 8: Food markets distribution in Cambodia with regional boundaries and (A) geographical characteristics or (B) population density. Note: The base map of elevation and population density was obtained from WorldPop while the map of inland water bodies was retrieved from the Open Development Mekong platform. Cambodia has four geographical regions, including the Plateau region that comprises of two discontiguous polygons.

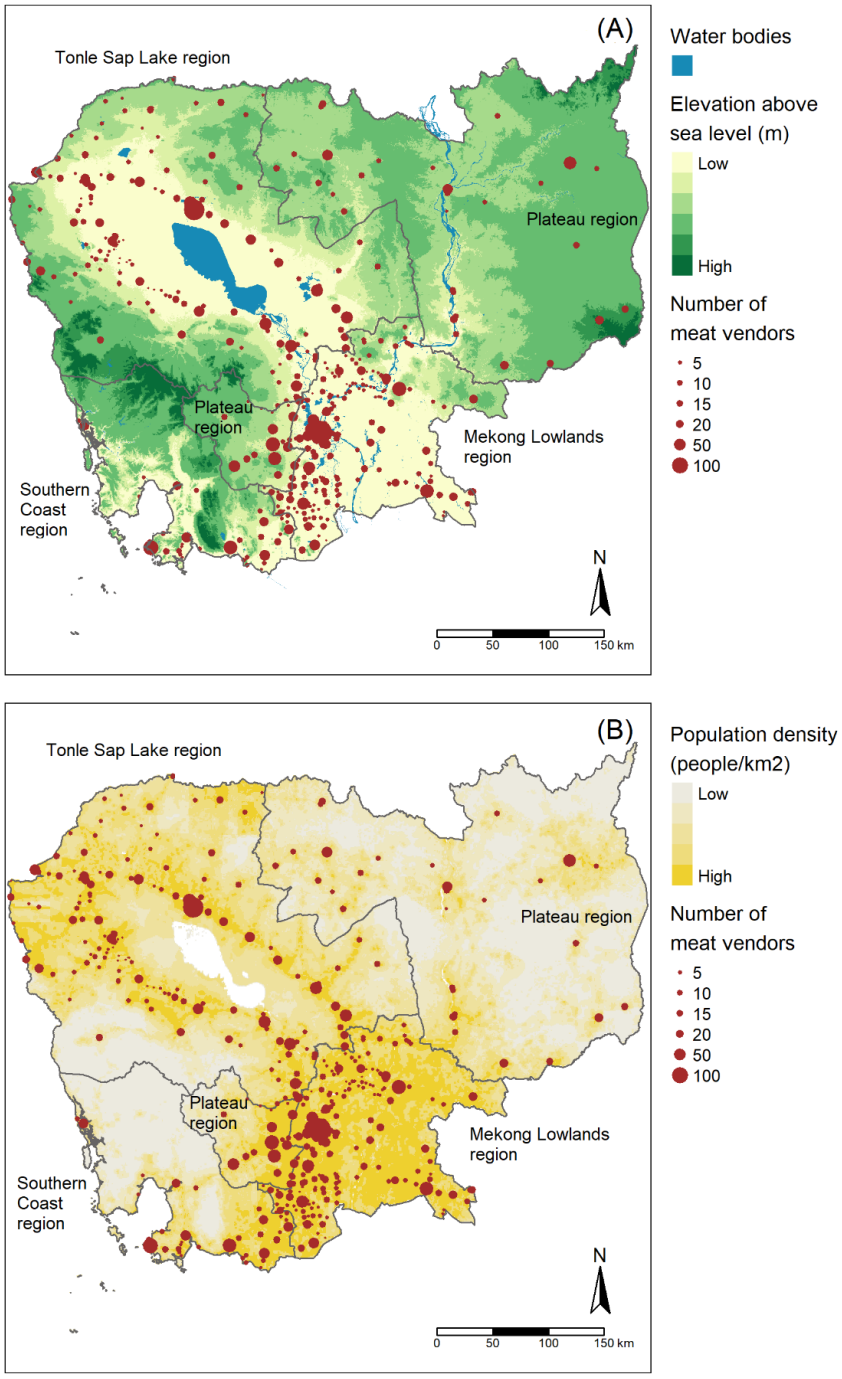


Figure 9: Straight-line distance from households to the nearest food markets

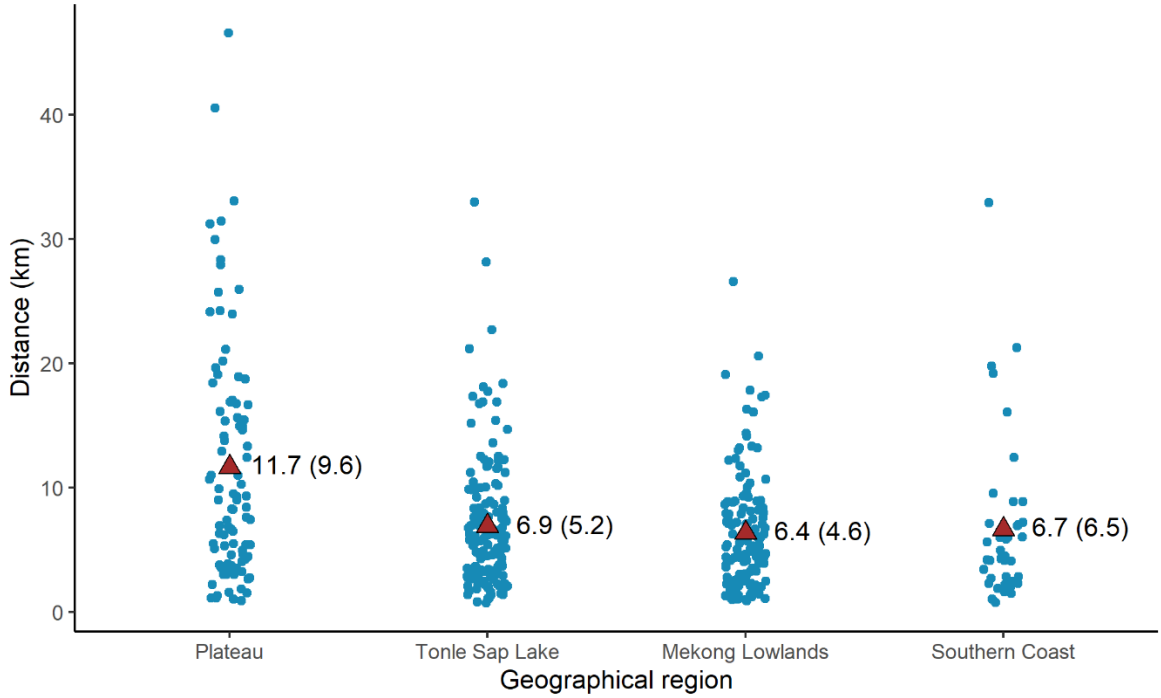


Table 5: Characteristics of the samples of children aged 6 to 23 months in rural Cambodia

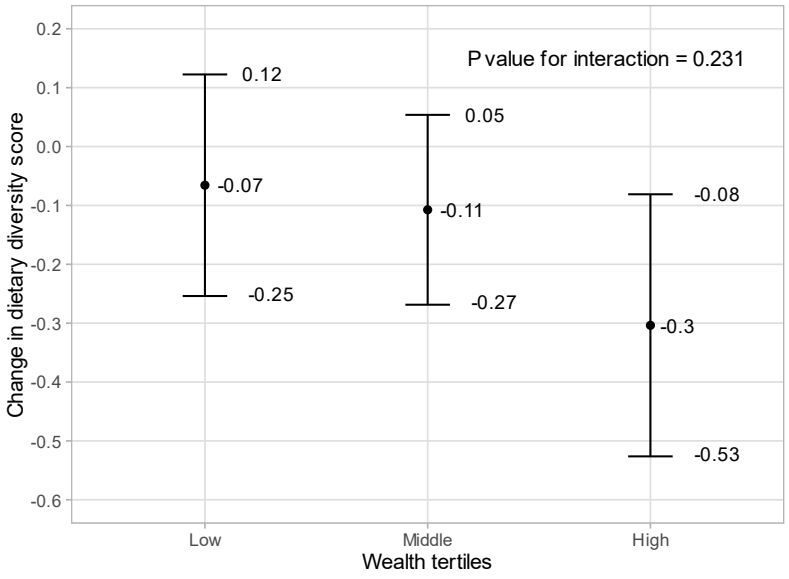
Covariates	Sample with dietary diversity data (n = 1537)	Sample with height-for-age Z-score data (n = 989)
Distance to market, *mean (SD)*	7.22 (5.98)	7.31 (6.09)
Dietary diversity score, *mean (SD)*	3.20 (1.62)	3.22 (1.61)
Height-for-age Z-score, *mean (SD)*	-1.25 (1.31)	-1.26 (1.31)
Child age, *mean (SD)*	14.35 (5.31)	14.47 (5.21)
Child sex, %		
Male	50.3	52.2
Female	49.7	47.8
Maternal age, %		
15-24 y	36.1	36.3
25-30 y	34.4	35.6
>30 y	29.4	28.1
Maternal education, %		
No education	14.6	14.0
Primary education[2]	54.5	59.3
Secondary education or more	31.0	26.7
Household wealth, %		
Low	30.1	31.4
Middle	32.1	31.8
High	37.9	36.8
Household size, %		
<=5 members	52.9	54.4
>5 members	47.1	45.6
Agricultural land ownership, %		
< 1 hectare	72.3	73.7
>= 1hectare	27.7	26.3
Livestock varieties, %		
None	24.7	23.9
1 variety	36.3	36.5
2 varieties	27.8	28.7
3-4 varieties	11.2	10.9
Region, %		
Mekong Lowlands	41.7	41.7
Tonle Sap Lake	35.4	33.9
Plateau	17.0	18.0
Southern Coast	5.9	6.4

Table 6: Associations of distance to nearest markets with children's dietary diversity score and height-for-age z-score in rural Cambodia

	Dietary diversity score (n = 1537)		Height-for-age z-score (n = 989)	
Covariates	Unadjusted model	Adjusted model[2]	Unadjusted model	Adjusted model[2]
(Log) distance to market[3]	-0.29 (-0.42, -0.17) **	-0.16 (-0.28, -0.05) **	-0.11 (-0.23, 0.02)	0.00 (-0.12, 0.11)
Child age	0.13 (0.11, 0.15) ***	0.13 (0.11, 0.14) ***	-0.07 (-0.08, -0.05) ***	-0.07 (-0.08, -0.05) ***
Child sex, Female vs. Male	-0.06 (-0.23, 0.11)	-0.08 (-0.22, 0.06)	0.14 (-0.03, 0.31)	0.13 (-0.04, 0.31)
Maternal age, vs. 15-24y				
25-30 y	0.28 (0.05, 0.51) *	0.18 (-0.02, 0.38)	-0.03 (-0.23, 0.18)	-0.02 (-0.22, 0.18)
>30 y	0.16 (-0.08, 0.41)	0.09 (-0.12, 0.30)	-0.13 (-0.37, 0.11)	-0.06 (-0.30, 0.17)
Maternal education, vs. No education				
Primary	0.19 (-0.05, 0.44)	0.18 (-0.07, 0.44)	-0.03 (-0.32, 0.25)	-0.22 (-0.48, 0.05)
Secondary	0.74 (0.40, 1.08) ***	0.54 (0.19, 0.88) **	0.09 (-0.22, 0.40)	-0.13 (-0.44, 0.19)
Household wealth, vs. Low				
Middle	0.39 (0.14, 0.63) **	0.39 (0.16, 0.62) ***	0.16 (-0.08, 0.40)	0.09 (-0.14, 0.31)
High	0.60 (0.31, 0.89) ***	0.44 (0.17, 0.71) **	0.51 (0.28, 0.74) ***	0.40 (0.14, 0.67) **
Household size, >5 members vs. <= 5 members	-0.15 (-0.35, 0.06)	-0.16 (-0.34, 0.01)	0.12 (-0.05, 0.29)	0.06 (-0.10, 0.23)
Agricultural land ownership, >= 1hectare vs. < 1 hectare	0.18 (-0.05, 0.42)	0.16 (-0.04, 0.37)	-0.14 (-0.35, 0.07)	-0.14 (-0.35, 0.07)
Livestock varieties, vs. None				
1 variety	-0.01 (-0.35, 0.33)	-0.03 (-0.30, 0.23)	-0.13 (-0.39, 0.13)	-0.01 (-0.27, 0.25)
2 varieties	-0.08 (-0.38, 0.23)	0.01 (-0.24, 0.26)	-0.22 (-0.46, 0.03)	-0.13 (-0.37, 0.12)
3-4 varieties	0.05 (-0.33, 0.43)	0.08 (-0.25, 0.41)	-0.24 (-0.60, 0.12)	-0.04 (-0.42, 0.34)
Region, vs. Mekong Lowlands				
Tonle Sap Lake	0.17 (-0.09, 0.42)	0.18 (-0.04, 0.39)	-0.13 (-0.36, 0.10)	-0.04 (-0.28, 0.19)
Plateau	-0.03 (-0.37, 0.30)	0.08 (-0.22, 0.37)	-0.35 (-0.65, -0.06)	-0.29 (-0.57, -0.01)*
Southern Coast	0.02 (-0.32, 0.36)	-0.02 (-0.33, 0.28)	0.34 (-0.04, 0.71)	0.31 (-0.07, 0.68)

Values are Mean different (95% Confidence interval), which were obtained from univariate or multivariate linear regression that accounts for Demographic and Health Survey's complex survey design. The adjusted models include all variables that were showed in this table. Distance was specified as the natural logarithm scale of the continuous distance. P-value: *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$*

Figure 10: Changes in dietary diversity score with a unit increase in naturally log transformed distance to nearest market



Notes: Error bars are 95% CIs of the marginal trends obtained from the post-hoc estimation of the multivariate linear regressions that included all covariates in Table 2 and an interaction term of distance to market and household wealth. The overall P-value was obtained from the Type 3 test.

Chapter 5: Understanding maternal food choice for preschool children across urban-rural settings in Vietnam

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5.1 Abstract

Improving diet quality for preschool children is challenging in countries undergoing food environment and nutrition transition. However, few studies have sought to understand how mothers in these countries decide what and how to feed their children. This study aims to explore maternal experiences, perspectives, and beliefs when making food choice decisions for preschool children in urban, peri-urban, and rural areas in northern Vietnam. Two focus group discussions and twenty-four in-depth interviews were carried out and analyzed using thematic analysis. The results showed that mothers across the urban-rural spectrum shared the intentions to feed children safe, nutritious food for better health and weight gain while satisfying child food preferences to improve appetite and eating enjoyment. These food choice intentions were embedded within family food traditions, whereby mothers emphasized nutritious food and adopted strict feeding styles during lunch and dinner but were flexible and accommodating of child preferences during breakfast and side meals. These intentions were also embedded within the physical food environment, which provided a mix of healthy and unhealthy food through informal food retailers. Despite these intentions, mothers faced financial constraints and difficulties in managing children's refusal to chew, changes in eating mood, and strong eating temperament. These findings support policies to limit the presence of unhealthy food in informal food retail and suggest the need for meal-specific feeding strategies to help children enjoy nutritious food, transition from soft to textured food, and become more cooperative during mealtime.

5.2 Introduction

Good nutrition during early life is vital for healthy growth and development throughout the life course (Adair et al., 2013; Cunningham et al., 2014). However, Vietnam is facing a rapid increase in child overweight and obesity while child stunting persists at a high level. In 2017, overweight and obesity prevalence among children under five reached 5.9% while the prevalence of child stunting was still as high as 20% (Global Nutrition Report, 2020; Phan et al., 2020). Both child overweight and child stunting can be linked to deficiencies of key micronutrients such as iron, zinc, and vitamin A (García et al., 2009; Millward, 2017), which are prevalent among children under five in both urban and rural areas (Le Nguyen et al., 2013).

Improving nutrition during early childhood in Vietnam is both enabled and constrained by the country's rapidly changing food system and food environment. On the one hand, fresh produce has become more available and accessible through sustained growth in agricultural production and ever-expanding food retail (Raneri et al., 2019; Trinh et al., 2020). On the other hand, commercial snacks and sugar-sweetened beverages have also become more accessible due to a rapid increase in manufacturing and marketing of commercial food (Baker & Friel, 2014). Additionally, food prices in Vietnam have increased for most categories of fresh food such as eggs, meat, and fruits while sugar has become more affordable over time (Harris et al., 2020). Increased public concern about pesticides and preservatives in fresh produce may also affect caregivers' decisions to purchase nutritious fresh food for their children (Nguyen-Viet et al., 2017). These changes in the food environment, coupled with improved living standards and accelerated urbanization, may prompt Vietnamese caregivers to prioritize cost, taste, and convenience over health and nutrition (Ruben et al., 2020).

Empirical work that examines caregivers' food choice behaviors in countries undergoing a changing food environment like Vietnam is lacking, since most studies of maternal food choice were carried out in high-income countries. These studies showed that food choice decision-making involved competing considerations such as child health, child hunger, child preference, monetary constraints, and time pressures (Boak et al., 2016; Pescud & Pettigrew, 2014). For example, Australian mothers from low-income households often experienced guilt and felt conflicted when deciding between feeding their children healthy food, keeping their children satiated, and securing their affections (Pescud & Pettigrew, 2014). Similarly, Dutch mothers recruited from daycare centers also opted for unhealthy food options due to high food cost and time scarcity despite initial intentions to feed children healthy food (Damen et al., 2020). Literature detailing maternal food choice decision-making is far more limited in low- and middle-income countries (LMIC). Studies of food insecure, rural farming households in Ethiopia and Tajikistan suggested that mothers emphasized satiety over nutrition and prioritized feeding children filling, starch-based cereals (Haileselassie et al., 2020; Kukeba et al., 2021), while studies of urban households in Nepal and Sri Lanka showed that mothers across different socioeconomic backgrounds often prioritized child preferences over health concerns (Sharma et al., 2019; Sirasa et al., 2020).

Theoretical models of caregiver's food choice behaviors are also limited. The food choice process model was developed in 1998 to explain how life course events and sociocultural context influence individuals' cognitive food choice process, which involves negotiations between conflicting values such as health, time, and cost (Furst et al., 1996). The model has been used widely to study food choice, but has been difficult to translate to practical strategies and messages in nutrition programs due to its broad scope and general application. In contrast, a recent gastronomic system research model was developed in 2020 as a toolkit to support policies and programs (Cuevas et al., 2017). It pointed to the prominent role of cultural food traditions in shaping eating occasions, which in turn determine the type of dishes, food ingredients, and consequently diet and nutrition, and thus provided a road map to gather a baseline understanding of local food choice and diet. However, both models target adult behavior and lack a discussion on caregiver-child relationships. This aspect was elaborated in the children's food choice process model developed in 2012 (Holsten et al., 2012), which also agreed with the gastronomic system research model that diet and food choice is specific to time and occasions.

This study aims to build on these theoretical models to understand how mothers in Vietnam make food choice decisions for their preschool children across urban-rural settings. Food choice decisions were defined broadly to encompass decisions of what food, how much, and how to feed children as all of these decisions were interrelated and consequential to child diet and nutrition. Maternal experiences across the urban-rural spectrum were documented in order to develop a more comprehensive understanding of their shared experiences and perspectives.

5.3 Methods

Study settings and design

This study was part of the CGIAR research program on agriculture, nutrition and health (A4NH) in Vietnam (de Haan et al., 2020). In each district of Cau Giay (urban), Dong Anh (peri-urban), and Moc Chau (rural), eight in-depth interviews (IDI) were carried out. Additionally, a focus group discussion (FGD) was held in each of the rural and peri-urban district. Cau Giay district (22,000 persons/m^2) is situated at the center of the

capital city of Hanoi and has recently emerged as a major commercial hub of the city. Dong Anh district (216 persons/m^2), located on the outskirts of Hanoi, is an agricultural area characterized by recent development in agriculture, services, and tourism. Moc Chau (105 persons/m^2) is a mountainous district in Son La province located in the northwestern region of Vietnam, where the primary economic activities are agriculture and livestock production. Unlike Cau Giay where less than 1% of households were living under the poverty line, 3% of the households in Dong Anh and 7% in Moc Chau were living under the poverty line (Huynh et al., 2021). All interviews and discussions took place from June to August 2019.

Recruitment and participants selection

Participating mothers were selected from the sampling frame of the A4NH program, which used probability proportional to size sampling to select 30 hamlets from each district and a random sample of low- and middle-income households in each hamlet. For the current study, the research team contacted all A4NH hamlet coordinators, who were the head of the hamlet responsible for disseminating information and organizing communal activities. Two hamlet coordinators in each district was then invited to support the present study. The hamlet coordinators made the first contact with mothers from the sampled households and referred interested mothers to the lead author, who explained the details of study participation in Vietnamese. Oral consent for study participation and permissions for audio recordings were obtained and formally recorded prior to conducting interviews or discussions. Ethical approval was obtained from the Emory University Institutional Review Board, United States (IRB00111930) and the Institutional Review Board at Hanoi School of Public Health in Vietnam (019-3251DD -YTCC).

Data collection

Mothers were asked about their perceptions and experiences in food acquisition, feeding practices, child eating behaviors, and child eating routines pertaining to all of their children between six months and six years of age. In several interviews, participants also recalled and reflected on their experiences feeding their older children when these children were less than six years of age. Since these past experiences were relevant and meaningful to understanding mothers' food choice, we also incorporated these data into the analysis.

Interviews were conducted at the participants' homes or hamlet's community halls. The research team consisted of the lead author and a research assistant. The lead author conducted the interviews and moderated the discussions while the research assistant took notes and managed audio recordings. The interviews lasted between 30 and 60 minutes and the focus group discussions lasted approximately 60 minutes each.

After each interview, the lead author wrote memos to reflect on the major or unexpected issues discussed by the participants. The interview guide was adapted based on salient issues from earlier interviews. All audio recordings were transcribed in Vietnamese by the lead author and then translated into English by professional translators.

Data analysis

All translated interviews and focus group discussions were deidentified and imported into MAXQDA, a qualitative data management software (VERBI Software GmbH, 1989). Thematic analysis using the inductive (data-driven) approach was used to identify patterns and nuances based on participants' experiences (Braun & Clarke, 2006; Chun Tie et al., 2019). In the first step, three independent coders including the lead author read and coded a set of six transcripts, which included two purposely selected transcripts from each interview site. Through a series of analytical meetings, the three coders discussed their codes and developed the codebook, which included code definitions, inclusion and exclusion criteria, and code examples. In the second step, the lead author applied the codebook to all the transcripts while the other two coders applied the codebook to a subset of two transcripts. The inter-rater agreements between the three coders were calculated to identify areas of disagreement and modify code definitions to improve the rigor of the codebook. In the third step, the lead author extracted text segments for each code, wrote code descriptions, identified code relations, and made comparisons between urban, peri-urban, and rural subgroups. Memos were written throughout to document evolving thoughts and ideas, which were shared with other coders and senior authors to ensure the objectivity of the interpretation. Theme saturation was reached since no new themes were obtained after analyzing two focus group discussions and eighteen in-depth interviews.

5.4 Results

A total of 24 in-depth interviews and 2 focus-group discussions were carried out. Of all participating mothers, approximately one third were farmers who cultivated a range of crops for sale and home consumption while others engaged in sales and services such as breakfast vendors and bus drivers or professional work such as school teachers and government officers. Most mothers, close to 80%, had children between 2 and 6 years of age while the remaining mothers either had children between 6 and 23 months of age or had children in both age groups. Over half reported living with or close to their biological parents or parents-in-law while others resided in different towns from where their parents lived (Supplementary table 1).

The key themes emerging from the interviews were arranged into broad categories of contextual influencers, food choice intentions, and food choice constraints (Figure 1). The key themes are summarized in Table 1 and elaborated below with support from short quotations provided in-text or long quotations listed as block quotes.

Contextual influencers

Physical food environment

Mothers' accounts revealed a heterogeneous food environment that provided a range of fresh food and commercial food products in close proximity. Typical sources of fresh food included food markets, backyard gardens, neighbors and family relatives, and to the lesser extent the wild environment such as rivers or wild fields. Fruits were considered more expensive than vegetables and seafood more expensive than pork. On the other hand, common sources of ready-to-eat food and commercial products such as fresh milk, formula milk, sweets, and sodas were supermarkets, home shops, street food vendors, and restaurants. Soft drinks were considered affordable while sweets had a range of different products varying in price, quantity, and quality. Hard candies or lollipops were sold in small package at cheap prices but sponge cakes were more expensive.

Food markets and backyard gardens are the most common sources of daily fresh food. All urban participants relied on nearby food markets for fresh food while their rural and peri-urban counterparts grew some or most of their fresh produce. Food markets existed in several forms, including formal supermarkets that sell

premium local and imported food products, semi-formal food markets selling more affordable local food products, or spontaneous markets ("*toad markets*") established along small streets selling fresh produce directly from farms.

Backyard gardens were also a convenient, affordable source of food in the peri-urban and rural areas. Leafy green vegetables were a commonly grown produce and often available year-round for consumption. Local fruits such as bananas, avocados, pomelos, and watermelons were also grown by some families but their availability was often seasonal. To the lesser extent, poultry was raised for egg and meat while pig and fish was farmed for meat only, although they required a growing period before they are ready for butchering and consumption.

Food sources varied in many aspects such as the ease of acquisition, perceived affordability, and perceived safety risks, which provided a range of options to suit different budgets and preferences. For example, several mothers frequented markets closest to their home for better proximity and convenience, several opted for large, commune markets to have a wider variety of choice, and some preferred "*toad markets"* due to the perceived affordability and safety:

> *"[The toad market] was on my way [to work] and the prices are reasonable, better than here. And because it is fresh from the farm so they are not industrially raised" (IDI-05, peri-urban, mother of a 4-year-old)*

Cultural food traditions

Mothers frequently discussed their choice of food and child feeding style in the context of cultural food traditions, including routines, social values, and meal structures associated with each eating occasion.

Dinner and lunch

Dinner was often prepared at home and referred to as "*family meals"*. Home-cooked meals with the presence of all family members were emphasized as an important tradition by most mothers, and often perceived to be more affordable, nutritious, and delicious than eating-out. As a result, mothers prioritized time to prepare meals for the family with the help from other family members such as husbands, parents, and in-laws. Eating

out was reported as a rare occurrence. Some mothers also referred to home-cooked meals as a symbol of family union:

> *"In my opinion, having delicious food at home makes people want to come home, so I want to make sure that our home food is delicious and enough for everybody" (DA-02, peri-urban, mother of a 2-year-old and 5-year-old)*

Lunch routines varied between families due to the differences in working hours and childcare arrangements. Some families took midday break from work to come home for a home-cooked lunch while other families had lunch at work. Nevertheless, a proper lunch and dinner were usually perceived as having all four dishes: rice, animal protein, vegetables, and vegetable soup. Vegetable soup was particularly emphasized as a required menu item:

> *"Vegetable soup must be available every day. If there is no vegetable soup, no one will eat. Everyone likes eating vegetable soup" (IDI-15, rural, mother of a 2-year-old).*

Due to this meal structure, mothers primarily gave children rice, vegetables, and meat for lunch and dinner and usually adopted various strategies, rules, and tactics to pressure or encourage their children to eat sufficient food. Some mothers also attempted to accommodate their children's preferences by modifying their cooking, such as deep-frying fish *"until it is crispy"* instead of making braised fish, or changing food options, such as making prawn dishes instead of pork dishes. Some established eating rules such as no snacks before dinner or finishing the bowls before leaving the table, while others used tactics such as sweet talk, letting children watch television, raising their voice at the children, or mixing pieces of vegetables or meat in the rice bowl without children's knowledge:

> *"I also have to scream and scold him at length before he eats some food. And I have to cut pork and beef into tiny pieces and mix in his rice so he doesn't know, then he will eat" (IDI-04, peri-urban, mother of a 4-year-old)*

Breakfast and side meals

Unlike lunch and dinner, during which the menu was well structured and consumption was enforced, breakfast and side meals were more flexible and diverse. Children's breakfasts typically involved milk and a range of starch-based dishes such as porridge, sticky rice, noodles, or Vietnamese baguettes, which could be

cooked at home, served by breakfast vendors in the neighborhood, or provided at daycares. During side meals such as afternoon snacks or evening desserts, there was a large range of fresh and commercial food options such as milk, fruits, fruit juice, yogurt, sponge cakes, candies, crisps, soft drinks, and ice-creams. While breakfasts are standard meals of the day, side meals were optional and dependent on family income and family daily routines.

Fruits were often served during side meals and, unlike meat and vegetables, were usually considered non-essential and supplementary. For many rural and peri-urban families, fruits were typically served one to three times a week while most urban mothers attempted to provide fruits to their children daily:s

> *"Fruits are an only side dish, just for dessert, but we cannot live without main dishes of rice, meat, vegetables. So, we still need fruits but it is just for the sake of having enough nutrients, for the sake of this and that" (FDG26, rural, mother of a 4-year-old)*

During side meals, mothers were more flexible and accommodating to their children's preferences. Mothers perceived side meals as occasions to keep children satiated between the main meals and to satisfy children's cravings. As a result, some mothers prioritized cookies and cakes over fruits and some let their children choose what to eat during these occasions:

> *"After the dinner, I let them eat cookies, cakes, candies, milk, ice-cream. Usually I will give them what they like" (IDI-11, urban, mother of a 4-year-old).*

Maternal food choice intentions

Promoting better health

All mothers emphasized feeding children safe, nutritious food to prevent illnesses and promote weight gain. Mothers commonly believed that vegetables, meat, and milk are nutritious, but had different thoughts about fruits, sweets, and sugar-sweetened beverages. While fruits were generally considered nutritious, vitamin-rich, and important for preventing constipation, some fruits were thought to upset an empty stomach and to be avoided after naptime or before dinner. Similarly, while some mothers restricted cookies and cakes due to the

concern of added sugars, other mothers encouraged their children consuming biscuits and sponge cakes, believing that they are a good source of nutrients. Likewise, some mothers believed that sugar-sweetened beverages were unhealthy for children due to high sugar content, but other mothers were unsure about their nutritional values:

> *"If he likes drinking [soft drinks], we have to buy it for him. I myself do not want to let him drink it, perhaps they are not so healthy (IDI-18, rural, mother of a 3-year-old)"*

Most mothers were greatly concerned about food safety, which was commonly discussed in relation to the use of additives in commercial products like sweets and crisps or the use of pesticides, growth hormones, and preservatives in meat, fruits, and vegetables. Low-priced commercial products such as lollipops or soft drinks sold by street vendors were perceived as carrying higher food safety risk than premium candies sold in the supermarkets. Fresh produce that was industrially farmed, sold by middlemen, and sold off-season was also believed to have higher content of harmful chemicals than seasonal produce grown by traditional farming and sold directly by farmers. Despite these concerns, few mothers reported limiting their purchase of meat or vegetables unless during times of a foodborne disease outbreak; rather they avoided specific kinds of produce, such as watermelons or tomatoes, diversified their sources of food, or obtained food directly from farmers rather than through markets.

According to mothers, body size was an indicator of healthy growth in children and having large children was socially desirable; as one mother commented, "*Of course everybody wants their children to be big and healthy*". Body size was often discussed using language related to weight such as skinny, thin, and chubby, and was judged by comparing their children to other children including cousins, classmates, and neighbors. When a child was perceived to be thin, mothers often became worried and attempted to feed their children more formula milk or starchy food. For example, a breastfed mother wanted to supplement her 9-month-old boy with formula milk to support weight gain, "*[He] is a bit underweight, so I plan to buy formula milk for him*". Another mother described giving her two-year-old daughter more cookies because she wanted her to gain weight: "*I give her more cookies because I think cookies have some starch for her. I think she is still thin."* Mothers of thin children also

encouraged or pressured their children to eat more while mothers of normal weight children were more relaxed:

> *"FGD-29: Your boy's weight is within the growth standards, so you don't have to pressure him too much. It's only the skinny ones that are worrying. FGD-32: Yes, that's why it's up to him to decide how much he eats" (FGD-29, mother of a 3-year old & FGD-32, mother of a 2-year-old, peri-urban)*

Many mothers described health as the absence of sickness. As a result, falling sick often signaled mothers to re-evaluate health risks. For example, mothers' decisions to avoid apples and watermelons, which were often perceived as having a high content of pesticides and additives, depended on their experiences of catching foodborne illnesses. Similarly, despite the common beliefs that sweets could lead to tooth decay and ice-cream could cause a sore throat, some mothers did not restrict sweets and ice-cream because their children had never experienced these symptoms:

> *"FGD-28: Thank goodness my boy tried ice-cream several times but he was fine, so I don't worry about it. FGD-29: Probably my boy has a weak throat, I don't dare let him have [ice-cream]" (FGD-28, mother of a 4-year-old & FGD-29, mother of a 3-year-old, peri-urban)*

Satisfying child preferences

Mothers also expressed intentions to satisfy their children's food preferences to ensure that their children enjoyed and consumed the meal. Children nevertheless differed widely in their food and taste preferences. Some refused meat but enjoyed fruits, some preferred meat to vegetables, and some showed little interest in food other than milk. Many enjoyed sweet tastes but some did not like "*too much sweet stuff*" and did not enjoy sugary cookies. Some children craved fast food while others preferred home-cooked meals over fast food or restaurant food.

"*What I want for my child is to be happy and healthy"*, a mother smiled as she explained why she often accommodated food requests from her two- and four-year old boys despite her precarious financial situation. Her quote reflects mothers' innate motivation to bring joy to children by satisfying their wants. This motivation was also reflected in other mothers' emphasis in eating enjoyment when buying food for children,

as one mother commented, "*He won't enjoy eating if I force him to eat because it will be tasteless"*. When mothers were asked what they would buy if they had surplus income, many indicated intentions to buy "*delicious", "rarely-seen", or "luxury"* food for children to try the taste.

In families with limited financial resources, mothers also attempted to satisfy their children's preferences by working extra hours to buy snacks or buying lower-quality and cheaper snacks:

> *"If I have money I will buy Chocopie [a popular snack cake], but I don't have money so I bought cheaper biscuits instead" (IDI-17, rural, mothers of a 3-year-old).*

Satisfying child preferences might also be a practical means to get children to consume their meals. This approach was rooted in mothers' beliefs that children only ate what they liked. As a result, mothers often changed the menu to improve children's appetite or experimented with different dishes to discover the food that children liked:

> *"Even if I give him nutritious food, it won't help if he doesn't eat it. I can only resolve this issue by buying food to cook and trying to change the menu to suit his taste buds" (DA-03, peri-urban, mother of a 5-year-old)*

Mothers' desire to get children to finish their food could be due to their emphasis on keeping children well-fed and satiated:

> "*I have to ensure my kids are fully stuffed whereas sometimes I myself only have dinner at 10PM. I can only be at ease if my kids are full" (FGD-29, peri-urban, mother of a 3-year-old)*

Maternal food choice constraints

Financial constraints

Lack of finance was a prominent concern among rural and peri-urban mothers. Most mothers were not able to acquire fruits daily both due the seasonality of fruits and its high price. In addition, a few mothers could not afford to have meat every day, usually due to housing debt or competing expenses such as utility bills or school fees. To these mothers, having farming assets such as backyards, livestock, or fish ponds provided an

important alternative. For example, one mother explained why she worked full time and also continued farming:

> *"Everyone says what's the point to do farming if you have a job. But we have many children and our finances are tight, there are so many expenses that we cannot handle all. Therefore, whatever I can do I will do it" (IDI05, peri-urban, mother of a 4-year-old)*

In the urban and peri-urban areas, meat, fruits, vegetables, and fresh milk were all considered affordable but some food such as seafood, imported fruits, or premium formula milk were considered expensive:

> *"I try to buy PediaSure formula milk for undernourished children for him to drink, but that one is quite pricy, so I quite hesitate" (IDI-34, urban, mother of a 5-year-old)*

Grandparents' influence

Over half of the mothers reported living with or close to their biological parents or parents-in-law, who often helped with meal preparation and childcare. However, many mothers disagreed with their parents about disciplining children when they refused eating or pestered for snacks. Additionally, grandparents' eating preferences might also influence mothers' food purchase for children. A mother noted that her father, who was in charge of food purchase and preparation, rarely bought fruits and usually served a limited variety of dishes for dinner that children may not like to eat. She often prepared extra food for the children while trying not to upset her father:

> *"My father will scold me if I buy too many fruits [to keep in the fridge] … He prefers fresh food so I try not buying too many" (IDI-34, urban, mother of a 5-year-old)*

Child chewing ability

Many children were perceived as not liking to chew or having difficulty in chewing, a trait mothers associated with food refusal and picky eating. One mother was frustrated that her four-year-old boy could not tear apart big pieces of meat and often refused to eat meat or vegetables. Other mothers also shared similar sentiments, reporting that their children either swallowed food without chewing or held food in their mouth until the

food became watery. As a result, many mothers made soft food for children through making broth or porridge, grinding, chopping, or stewing while avoiding feeding children rice or whole pieces of meat or vegetables. This practice was also common among mothers of children aged two or beyond:

> *"I usually buy meats or bones to make broth and boil them with vegetables. She is very lazy at eating full pieces of meat, [she] does not like chewing, so I always have to cook meat to make broth and mostly use the broth" (FGD26, rural, mother of a 4-year-old)*

Child eating mood and temperament

In our framework, child eating mood refers to children's temporary, context-specific attitudes and feelings towards food and eating. In contrast, child eating temperament could be understood as children's habitual emotions and reactions towards food and eating. According to mothers, it is how strongly their children express their preferences, and not the preference itself, that prompted mothers to change their food choice for children. The manifestation of child temperament such as crying, throwing tantrums, or pestering could lead to mealtime struggles:

> "*She eats whatever dishes I make, but never touches any vegetables. If I insist that she drinks a bowl of vegetable soup she will cry for 15 minutes*" *(FGD27, peri-urban, mother of a 2-year-old)*

Eating temperament explains why child eating behaviors changed as children grew older; as a mother noted, "*Now it's not so bad but when he was two, he would whine [for snacks] whenever I brought him out".* On the other hand, child eating mood explains why child food preference varied from day to day. Several mothers noted that their children only had fruits or fruit juice when they were "*in the mood*". Eating mood could be influenced by external distractions such as playing:

> *"Today they craved for fish so I bought fish, but many times I bought fish and they did not eat. Many times, they are too interested in playing that they only eat plain rice with vegetable soup and then continue playing"* (*IDI-14, rural, mother of a 2-year-old and a 6-year-old)*

5.5 Discussion

This study reveals important insights into mothers' intentions and constraints when making food choice decisions for their preschool children. Across the urban-rural spectrum, maternal food choice decisions were embedded within the physical food environment and cultural food traditions. Such context facilitated mothers' dual intentions in feeding children nutritious food to promote health and weight gain and satisfying child preferences to help them enjoy their meals. However, many mothers were unable to realize these intentions due to various constraints. Some had difficulties in managing children's refusal to chew, changing eating mood, and strong eating temperament. Some had disagreements with grandparents about feeding practices and, specific to rural and peri-urban areas, some faced financial constraints due to limited income and competing spending. As a result, mothers had to balance these constraints against their intentions to make decisions what and how to feed children.

A novel finding in our study is the variation in maternal choice of food and feeding styles by meal occasions. Quite often, mothers promoted nutritious fresh food and adopted a strict feeding style during lunch and dinner but were flexible and accommodating to children's preferences with a mix of fresh and packaged food during side meals. In other words, although cooking food separately for children was common in our study setting, food choice for children did not deviate far from, or at least not contradict, family meal routines and traditions. This finding emphasizes the notion that an important aspect of child feeding is the gradual incorporation of family diet and eating routines (A. C. Klassen et al., 2019) and that eating behaviors are embedded within family food traditions (Cuevas et al). In Vietnam, lunch and dinner are home-cooked and involve a nutritious combination of rice, vegetables, and protein dishes. Mothers in our study highly regarded the tradition of home-cooked meals and did not consider time as a barrier to meal preparation, which differs from earlier studies (Ann C. Klassen et al., 2019; Sharma et al., 2019). In contrast to lunch and dinner, side meals like afternoon snacks and evening desserts were occasions for children to enjoy the food they like, which ranged from fruits, yogurts to cookies and ice-creams. Some mothers preferred giving cookies rather than fruits due to the beliefs that cookies can help fill stomach and that fruits can upset an empty stomach. These perceptions, combined with the high cost and seasonality of fruits, might explain the

underconsumption of fruits among Vietnamese children and general adults (Bui et al., 2016; Huynh et al., 2021).

Our characterization of meal-specific food choice and feeding styles has important implications for nutrition programming. Broadly, changing eating behaviors and feeding styles requires identifying culturally-specific sets of eating occasions and understanding routines, structures and social values of each occasion. Specifically, in our setting, interventions that promote fruits consumption in preschool children should frame their messages in the context of side-meals, address myths surrounding fruits, emphasize the importance of fruits in child growth, and advise mothers to replace high-sugar snacks with healthier but equally filling fruits locally available such as bananas and avocados. On the other hand, given mothers' strong emphasis on meat and vegetables in children's diet, interventions to promote meat and vegetables need not focus on health benefits but rather on responsive feeding strategies to improve chewing ability, address food refusal, and encourage positive eating behaviors.

Another key finding in our study is the prominent role of child eating behaviors in influencing maternal food choice. Many children were considered having a strong temperament, which manifested into tantrums, crying, or pestering for food. These behaviors nevertheless reflect natural psychological changes during early childhood, a phase when children develop a sense of autonomy, learn to express their emotions, and exercise their preferences (Walton et al., 2017). When dealing with these behaviors, a few mothers employed responsive approaches such as explanation, encouragement, and consistent discipline while the majority employed reactive approaches such as feeding children only the food they wanted, appeasing children with sugary food, raising their voice to enforce eating, or distracting children with televisions. These reactive approaches have been documented in earlier studies in Vietnam and other LMIC (Do et al., 2015; Hurley et al., 2011) and could stem from mothers' innate desire to fulfill children's food requests to ensure that children have a good appetite, enjoy their meals, and finish their food. These approaches might also reflect mothers' desire to help children gain weight, which was to mother an indication of healthy growth (Flax et al., 2016; Waldrop et al., 2016). These results suggest the need to design feeding interventions to help mothers and

other caregivers aware about optimal body weight in children, understand children's natural psychological development, and reinforce good eating behaviors in children.

Previous studies often discussed child eating behaviors in terms of taste preferences, but our study showed that chewing difficulty is also central to understanding food refusal and picky eating in children. According to mothers in our study, children had diverse preferences from liking to disliking sweets or from preferring fast food to enjoying home-cooked meals. Such diverse preferences were in contrast to the hypothesis about innate child preference for sweetness and against bitterness (Beauchamp & Mennella, 2009), but they were aligned with the notion that taste preference is continually molded throughout early childhood under the influence of the social environment (Forestell, 2017). The maturation of oral-motor skills for effective chewing, however, has a shorter window of opportunity (Gisel, 1991). According to the Infant and Young Child Feeding guidelines, children should be transitioned from soft food to textured, family food by 12 months of age to ensure effective chewing (WHO, 2005). Many mothers in our study did not follow this recommendation and instead continued feeding their children porridge mixed with meat broth or ground meat beyond two years of age. Such prolonged feeding of soft foods has been documented in high-income settings and shown to be associated with feeding difficulty and low intake of fruits and vegetables (Coulthard et al., 2009; Tournier et al., 2021). In LMIC, the delay of giving complementary food has been documented, but the delayed progression from soft to textured food has not been well explored. Future work in Vietnam and LMIC should assess the prevalence of such feeding practice, the extent of child chewing difficulty, and their effects on child diet.

One important finding in our study is that rural mothers who considered their families food insecure also desired to feed children delicious food or food that children crave for, often through stretching their budget to buy cheap snacks. This finding was in contrast to studies of rural, food-insecure mothers in Ethiopia and Tajikistan, which showed that child satiety but not child preference and eating enjoyment was the key food choice intention (Haileselassie et al., 2020; A. C. Klassen et al., 2019). It is possible that the stronger economic growth in Vietnam relative to Ethiopia and Tajikistan have led to better purchasing power for most people, including the food insecure mothers in our study, and in parallel the wider presence of unhealthy snack food

and thus higher children's exposure to these products in rural Vietnam. The allocation of budget to unhealthy food in families where children did not have adequate diet is undesirable to improving children's nutrition. Future work should examine child food preference and eating behaviors in low-income, food-insecure households and assess how these factors exacerbate the impact of food insecurity on child diet.

All mothers in our study had physical access to a range of nutritious fresh food and nutrient-poor packaged products, which were supplied mostly through informal food markets, backyard gardens, home shops and street food vendors. Such heterogeneity in the food environment, which has been documented in other LMIC (Duong et al., 2021; Downs, Ahmed, Fanzo, & Herforth, 2020), helped mothers in our study procure food that fit their budget and preferences. This finding suggests a caution to the recent policy in Vietnam that aimed to modernize food retails through promoting supermarkets and tightening regulations of informal markets, which could limit choices for mothers (MoIT, 2009; Moustier. P, 2006). Rather, more deliberate policies are needed to strengthen the existing informal food markets and, among communities experiencing food insecurity, promote home gardens or communal gardens to help families buffer the lack of financial means to purchase food. In parallel, informal food retailers such as home shops and convenience stores should be incentivized to limit the sales of unhealthy beverages and snacks to create a healthier food environment.

Our conceptual model leverages the strengths of existing food choice models while presenting unique understanding of caregivers' food choice behaviors for preschool children. Our model is similar to the children's food choice process model designed specifically for food choice behaviors during adolescence (Holsten et al., 2012). Both models accentuate the role of caregiver-child interactions in shaping food choice and diet, but we identified key constructs unique to eating behaviors in preschool children such as chewing ability and eating enjoyment. The gastronomic system research model (Cuevas et al., 2017) and food choice process model (Furst et al., 1996) both target adult food choice and thus lack the component of caregiver-child interactions. While our study aligns with the gastronomic system research model's premise that food choice behaviors are specific to eating occasions and shaped by cultural food practices, our model also encompasses the cognitive factors including young children's ability to negotiate which food they consume.

Similar to the food choice process model, our model also emphasizes that food choice decisions are ultimately a balancing act between many considerations. By complementing existing food choice theories, our model enables better understanding of caregivers' food choice for preschool children and provides a framework for future research in this area while lending specific suggestions to nutritional programs in Vietnam and similar country contexts.

A key strength of this study is the diverse sample of respondents across urban, peri-urban and rural households, which enabled the understanding of commonalties in maternal experiences and perspectives. However, the study is not without limitations. First, the field work took place in the communities where food markets existed within walking distance and thus the results cannot be generalized to neighborhoods which are without nearby markets. Secondly, due to the exploratory nature of this study, not all themes could be fully examined and conceptualized. For example, although we have documented the role of grandparents in influencing mothers' food choice and feeding styles, we lacked data on other aspects of social networks such as peers and community health workers. Previous research has shown that social networks inside and outside family can play a vital role in nudging mothers towards more optimal child feeding practices (Reyes et al., 2022). How social networks affect mother-child dynamics should be a focus of future research. Lastly, due to logistical constraints, the focus group discussion in the urban area was not carried out as planned, which might have limited the insights gathered from urban participants.

5.6 Conclusion

Literature on child diet and feeding practices has often contrasted between healthy and unhealthy diet and between responsive, authoritative, and indulgent feeding styles. Our study suggests that mothers in northern Vietnam did not adopt a single diet or feeding style for their children, but rather changed their choices throughout the day. Nutritious food was emphasized and enforced during lunch and dinner while child preferences for unhealthy food were often accommodated during afternoon snacks or evening desserts. These practices reflected family food traditions in Vietnam and mothers' dual intentions in feeding children nutritious food to promote weight gain and satisfying child preferences to increase eating enjoyment. The

reported food practices might also reflect mothers' attempts in managing child eating behaviors, including the refusal to chew, changing eating mood and strong eating temperament. These findings suggest the need to design meal-specific feeding strategies to help mothers and other caregivers increase children's enjoyment of nutritious food, respond effectively to children's mood and temperament, and encourage children to transition from soft to textured food.

5.7 References

Adair, L. S., Fall, C. H. D., Osmond, C., Stein, A. D., Martorell, R., Ramirez-Zea, M., Sachdev, H. S., Dahly, D. L., Bas, I., Norris, S. A., Micklesfield, L., Hallal, P., & Victora, C. G. (2013). Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: findings from five birth cohort studies. *The Lancet*, *382*(9891), 525-534. https://doi.org/https://doi.org/10.1016/S0140-6736(13)60103-8

Baker, P., & Friel, S. (2014). Processed foods and the nutrition transition: evidence from Asia [https://doi.org/10.1111/obr.12174]. *Obesity Reviews*, *15*(7), 564-577. https://doi.org/https://doi.org/10.1111/obr.12174

Beauchamp, G. K., & Mennella, J. A. (2009). Early flavor learning and its impact on later feeding behavior. *Journal of Pediatric Gastroenterology and Nutrition*, *48 Suppl 1*, S25-30. https://doi.org/https://doi.org/10.1097/MPG.0b013e31819774a5

Boak, R., Virgo-Milton, M., Hoare, A., de Silva, A., Gibbs, L., Gold, L., Gussy, M., Calache, H., Smith, M., & Waters, E. (2016). Choosing foods for infants: a qualitative study of the factors that influence mothers. *Child: Care, Health and Developmen*, *42*(3), 359-369. https://doi.org/https://doi.org/10.1111/cch.12323

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101. https://doi.org/https://doi.org/10.1191/1478088706qp063oa

Bui, T. V., Blizzard, C. L., Luong, K. N., Truong Nle, V., Tran, B. Q., Otahal, P., Srikanth, V., Nelson, M. R., Au, T. B., Ha, S. T., Phung, H. N., Tran, M. H., Callisaya, M., Smith, K., & Gall, S. (2016). Fruit and

vegetable consumption in Vietnam, and the use of a 'standard serving' size to measure intake. *British Journal of Nutrition*, *116*(1), 149-157. https://doi.org/https://doi.org/10.1017/s0007114516001690

Chun Tie, Y., Birks, M., & Francis, K. (2019). Grounded theory research: A design framework for novice researchers. *SAGE open medicine*, *7*(2), 2050312118822927. https://doi.org/https://doi.org/10.1177/2050312118822927

Coulthard, H., Harris, G., & Emmett, P. (2009). Delayed introduction of lumpy foods to children during the complementary feeding period affects child's food acceptance and feeding at 7 years of age. *Maternal & Child Nutrition*, *5*(1), 75-85. https://doi.org/https://doi.org/10.1111/j.1740-8709.2008.00153.x

Cuevas, R. P., de Guia, A., & Demont, M. (2017). Developing a framework of gastronomic systems research to unravel drivers of food choice. *International Journal of Gastronomy and Food Science*, *9*, 88-99. https://doi.org/https://doi.org/10.1016/j.ijgfs.2017.06.001

Cunningham, S. A., Kramer, M. R., & Narayan, K. M. V. (2014). Incidence of Childhood Obesity in the United States. *New England Journal of Medicine*, *370*(5), 403-411. https://doi.org/https://doi.org/10.1056/NEJMoa1309753

Damen, F. W. M., Luning, P. A., Hofstede, G. J., Fogliano, V., & Steenbekkers, B. (2020). Value conflicts in mothers' snack choice for their 2- to 7-year-old children. *Maternal & Child Nutrition*, *16*(1), e12860. https://doi.org/https://doi.org/10.1111/mcn.12860

de Haan, S., Huynh, T., Duong, T. T., & Rubin, J. (2020). *Defining the benchmark research sites (rural to urban transect) in Vietnam*.

Do, L. M., Eriksson, B., Tran, T. K., Petzold, M., & Ascher, H. (2015). Feeding of preschool children in Vietnam: a study of parents' practices and associated factors. *BMC Nutrition*, *1*(1), 16. https://doi.org/https://doi.org/10.1186/s40795-015-0011-0

Flax, V. L., Thakwalakwa, C., & Ashorn, U. (2016). Perceptions of Child Body Size and Health Care Seeking for Undernourished Children in Southern Malawi. *Qualitative health research*, *26*(14), 1939-1948. https://doi.org/https://doi.org/10.1177/1049732315610522

Forestell, C. A. (2017). Flavor Perception and Preference Development in Human Infants. *Annals of Nutrition and Metabolism*, *70(suppl 3)*(Suppl. 3), 17-25. https://doi.org/https://doi.org/10.1159/000478759

Furst, T., Connors, M., Bisogni, C. A., Sobal, J., & Falk, L. W. (1996). Food choice: a conceptual model of the process. *Appetite*, *26*(3), 247-265. https://doi.org/https://doi.org/10.1006/appe.1996.0019

García, O. P., Long, K. Z., & Rosado, J. L. (2009). Impact of micronutrient deficiencies on obesity. *Nutrition Reviews*, *67*(10), 559-572. https://doi.org/https://doi.org/10.1111/j.1753-4887.2009.00228.x

Gisel, E. G. (1991). Effect of food texture on the development of chewing of children between six months and two years of age. *Developmental Medicine & Child Neurology*, *33*(1), 69-79. https://doi.org/https://doi.org/10.1111/j.1469-8749.1991.tb14786.x

Global Nutrition Report. (2020). *Country Nutrition Profiles*. Retrieved December from https://globalnutritionreport.org/resources/nutrition-profiles/

Haileselassie, M., Redae, G., Berhe, G., Henry, C. J., Nickerson, M. T., Tyler, B., & Mulugeta, A. (2020). Why are animal source foods rarely consumed by 6-23 months old children in rural communities of Northern Ethiopia? A qualitative study. *Plos One*, *15*(1), e0225707. https://doi.org/https://doi.org/10.1371/journal.pone.0225707

Harris, J., Nguyen, P. H., Tran, L. M., & Huynh, P. N. (2020). Nutrition transition in Vietnam: changing food supply, food prices, household expenditure, diet and nutrition outcomes. *Food Security*, *12*(5), 1141-1155. https://doi.org/https://doi.org/10.1007/s12571-020-01096-x

Holsten, J. E., Deatrick, J. A., Kumanyika, S., Pinto-Martin, J., & Compher, C. W. (2012). Children's food choice process in the home environment. A qualitative descriptive study. *Appetite*, *58*(1), 64-73. https://doi.org/https://doi.org/10.1016/j.appet.2011.09.002

Hurley, K. M., Cross, M. B., & Hughes, S. O. (2011). A systematic review of responsive feeding and child obesity in high-income countries. *Journal of Nutrition*, *141*(3), 495-501. https://doi.org/https://doi.org/10.3945/jn.110.130047

Huynh, T. T. T., Pham, H. T. M., Trinh, H. T., Duong, T. T., Nguyen, T. M., Hernandez, R., Lundy, M., Nguyen, K. T., Nguyen, L. L. T., Vuong, V. T., H.T., N., Truong, M. T., Do, H. P. T., Ranneri, J., HongKy, T., & de Haan, S. (2021). *Partial food systems baseline assessment at the Vietnam benchmark sites*.

Klassen, A. C., Milliron, B. J., Suehiro, Y., Abdulloeva, S., Leonberg, B., Grossman, S., Chenault, M., Bossert, L., Maqsood, J., Abduzhalilov, R., & Iskandari, M. (2019). "Then you raise them with Shirchoy or cookies": Understanding influences on delayed dietary diversity among children in Tajikistan. *Maternal & Child Nutrition*, *15*(2), e12694. https://doi.org/https://doi.org/10.1111/mcn.12694

Klassen, A. C., Milliron, B. J., Suehiro, Y., Abdulloeva, S., Leonberg, B., Grossman, S., Chenault, M., Bossert, L., Maqsood, J., Abduzhalilov, R., & Iskandari, M. (2019). "Then you raise them with Shirchoy or cookies": Understanding influences on delayed dietary diversity among children in Tajikistan [https://doi.org/10.1111/mcn.12694]. *Maternal & Child Nutrition*, *15*(2), e12694. https://doi.org/https://doi.org/10.1111/mcn.12694

Kukeba, M. W., Fallon, D., & Callery, P. (2021). Child feeding in rural northern Ghana: Carer's perceptions of food and their children's diets [https://doi.org/10.1111/mcn.13085]. *Maternal & Child Nutrition*, *17*(2), e13085. https://doi.org/https://doi.org/10.1111/mcn.13085

Le Nguyen, B. K., Le Thi, H., Nguyen Do, V. A., Tran Thuy, N., Nguyen Huu, C., Thanh Do, T., Deurenberg, P., & Khouw, I. (2013). Double burden of undernutrition and overnutrition in Vietnam in 2011: results of the SEANUTS study in 0·5-11-year-old children. *British Journal of Nutrition*, *110 Suppl 3*, S45-56. https://doi.org/https://doi.org/10.1017/s0007114513002080

Millward, D. J. (2017). Nutrition, infection and stunting: the roles of deficiencies of individual nutrients and foods, and of inflammation, as determinants of reduced linear growth of children. *Nutrition Research Reviews*, *30*(1), 50-72. https://doi.org/https://doi.org/10.1017/s0954422416000238

MoIT. (2009). *Overview of the current status and direction of economic and social development in Hanoi in 2010, with a vision to 2030*.

Moustier. P. (2006). *Trends and policy on markets and supermarkets in Vietnam*.

Nguyen-Viet, H., Tuyet-Hanh, T. T., Unger, F., Dang-Xuan, S., & Grace, D. (2017). Food safety in Vietnam: where we are at and what we can learn from international experiences. *Infectious Diseases of Poverty*, *6*, Article 39. https://doi.org/10.1186/s40249-017-0249-7

Pescud, M., & Pettigrew, S. (2014). 'I know it's wrong, but...': a qualitative investigation of low-income parents' feelings of guilt about their child-feeding practices. *Maternal & Child Nutrition*, *10*(3), 422-435. https://doi.org/https://doi.org/10.1111/j.1740-8709.2012.00425.x

Phan, H. D., Nguyen, T. N. P., Bui, P. L., Pham, T. T., Doan, T. V., Nguyen, D. T., & Van Minh, H. (2020). Overweight and obesity among Vietnamese school-aged children: National prevalence estimates based on the World Health Organization and International Obesity Task Force definition. *Plos One*, *15*(10), e0240459. https://doi.org/https://doi.org/10.1371/journal.pone.0240459

Raneri, J. E., Kennedy, G., Nguyen, T., Wertheim-Heck, S., Do, H., de Haan, S., Nguyen, P. H., Le, T. H., Truong, T. M., Duong, T. T., Duong, M.-C., Nguyen, T. L., & Bene, C. (2019). *Determining key research areas for healthier diets and sustainable food systems in Viet Nam.* (IFPRI Discussion Paper 1872, Issue.

Reyes, L. I., Frongillo, E. A., Moore, S., Blake, C. E., Gonzalez, W., & Bonvecchio, A. (2022). Functions of social networks in maternal food choice for children in Mexico [https://doi.org/10.1111/mcn.13263]. *Maternal & Child Nutrition*, *18*(1), e13263. https://doi.org/https://doi.org/10.1111/mcn.13263

Ruben, R., Grace, D., & Lundy, M. (2020). *Supporting consumer choices towards healthy, safe and sustainable diets in low-and middle-income countries: Contributions to policy and research priorities for CGIAR*.

Sharma, N., Ferguson, E. L., Upadhyay, A., Zehner, E., Filteau, S., & Pries, A. M. (2019). Perceptions of commercial snack food and beverages for infant and young child feeding: A mixed-methods study among caregivers in Kathmandu Valley, Nepal. *Maternal & Child Nutrition*, *15 Suppl 4*(Suppl 4), e12711. https://doi.org/https://doi.org/10.1111/mcn.12711

Sirasa, F., Mitchell, L., Silva, R., & Harris, N. (2020). Factors influencing the food choices of urban Sri Lankan preschool children: Focus groups with parents and caregivers. *Appetite*, *150*, 104649. https://doi.org/https://doi.org/10.1016/j.appet.2020.104649

Tournier, C., Bernad, C., Madrelle, J., Delarue, J., Cuvelier, G., Schwartz, C., & Nicklaus, S. (2021). Fostering infant food texture acceptance: A pilot intervention promoting food texture introduction between 8 and 15 months. *Appetite*, *158*, 104989. https://doi.org/https://doi.org/10.1016/j.appet.2020.104989

Trinh, H. T., Dhar, B. D., Simioni, M., de Haan, S., Huynh, T. T. T., Huynh, T. V., & Jones, A. D. (2020). Supermarkets and Household Food Acquisition Patterns in Vietnam in Relation to Population Demographics and Socioeconomic Strata: Insights From Public Data [Original Research]. *Frontiers in Sustainable Food Systems*, *4*(15). https://doi.org/https://doi.org/10.3389/fsufs.2020.00015

VERBI Software GmbH. (1989). *MAXQDA: The art of data analysis*. https://www.maxqda.com/about

Waldrop, J. B., Page, R. A., & Bentley, M. E. (2016). Perceptions of Body Size in Mothers and Their Young Children in the Galapagos Islands. *Maternal and Child Health Journal*, *20*(10), 2012-2018. https://doi.org/https://doi.org/10.1007/s10995-016-2022-0

Walton, K., Kuczynski, L., Haycraft, E., Breen, A., & Haines, J. (2017). Time to re-think picky eating?: a relational approach to understanding picky eating. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 62. https://doi.org/https://doi.org/10.1186/s12966-017-0520-0

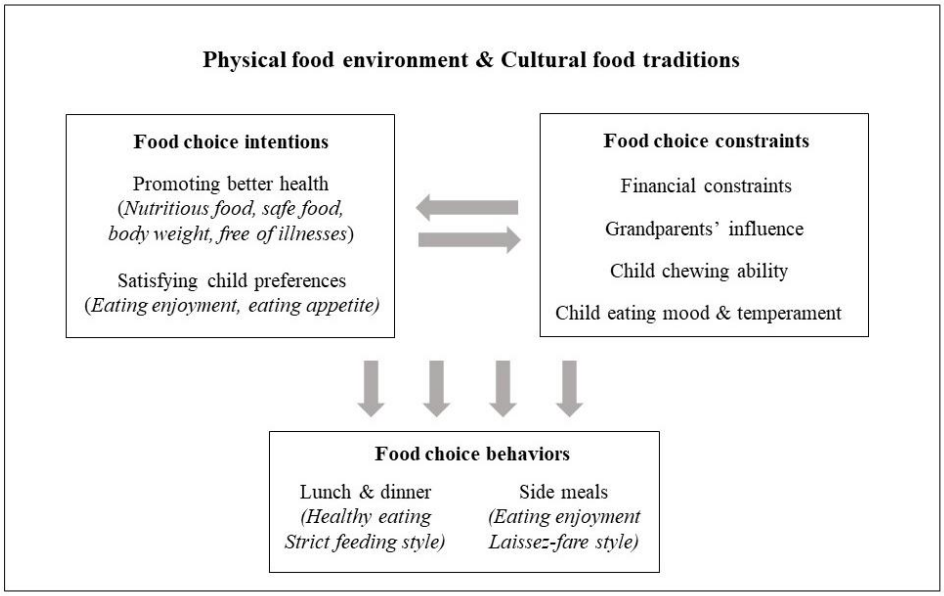
WHO. (2005). *Guiding principles for feeding non-breastfed children 6-24 months of age*.

5.8 Figures & tables

Table 7: Summary of broad categories and key themes

Categories	Themes	Key findings
Contextual influencers	Physical food environment	Food was available in many forms of retail establishments: supermarkets, commune markets, village markets, and toad markets (self-organized markets along small streets). Food was also available through other sources: backyard gardens, neighbors and relatives, and the wild environment (rivers and wild fields). Food sources varied in key characteristics: price, freshness, safety, and hours of operation.
	Cultural food traditions	Family meals (lunch and dinner) were perceived to be important, nutritious, delicious, and the symbol of family union. They consist of rice, animal protein, vegetables, and vegetable soup. Breakfasts were usually starch-based while side meals (afternoon snacks and evening desserts) provided a wide selection of fresh fruits, milk, yogurts, crisps, sweets, and pastries. Family meals were often the occasions when mothers adopted strict feeding styles to promote nutritious food while side meals were occasions when mothers were flexible and accommodating to child food preferences.
Food choice intentions	Promoting health	Mothers perceived health in terms of weight gain and the absence of illnesses. Mothers wanted to provide nutritious food but showed concern for food high in pesticides, preservatives, and additives.
	Satisfying child preference	Mothers expressed an innate desire to see children enjoy their meals and to improve children's appetite and thus satiety. Some mothers devised strategies to satisfy child preferences within a limited budget.
Food choice constraints	Financial constraints	Finance was discussed as a barrier to purchasing meat and fruits by some rural participants and to purchasing premium formula milk by some peri-urban and urban participants. Growing food for home consumption helped buffer financial constraints among rural participants.
	Grandparents' influence	Grandparents provided support in meal preparation and childcare. However, some mothers disagreed with grandparents about disciplining eating behaviors in children. Grandparent's eating preferences also influenced mothers' food purchase for children.
	Child chewing difficulty	Refusing to chew and having difficulty in chewing textured food was perceived as a common problem in children. Prolonged feeding of soft food such as porridge, meat broth, and ground meat was common in children over two years of age.
	Child eating mood and temperament	Children's mood for eating changed from day to day. Children also varied widely in how they asserted their food preference.

Figure 11: Conceptual model of intentions and constraints underlying maternal food choice for children



Chapter 6: Discussion & Conclusion

The goal of this dissertation is to characterize the temporality of diet and eating patterns in early life and the linkage between food environment and child diet in rural Vietnam and Cambodia. To pursue this goal, we first characterized the temporal patterns of minimum dietary diversity over the period between 6 and 24 months of age and assessed the relationships between these patterns and child growth outcomes in a birth cohort in rural Vietnam (Chapter 3). We then dived into understanding how access to fresh food markets is related to dietary diversity score among rural children in Cambodia (Chapter 4). Lastly, we complemented our quantitative results presented in Chapter 3 and 4 with findings from the in-depth interviews and focus-group discussions with mothers of young children, in which we explored the temporality of child eating patterns, mothers' perception of food environment and their food choice behaviors (Chapter 5). In this chapter, we will first triangulate key findings across the three research aims to discuss our key contributions to research. We will then elaborate on the key strengths and limitations and then conclude the chapter by a discussion of public health implications for future research, programs and policy-making.

6.1 Summary of key findings

Across the three research aims, our research contributes to literature of temporal dietary patterns, the role of food markets in child diet, and parental food choice behaviors (Table 8).

Chapter 3 revealed that indeed, there are strong variations in the temporal patterns of minimum dietary diversity over time. These variations are explained by the timing of the minimum diverse diet and the stability of the minimum diverse diet over time. While prior studies have raised the concern about the delayed initiation of diverse diet (Dickin et al., 2021), we pointed out that maintenance of diverse diet is also an important problem. In our sample, less than a third of the children followed the optimal pattern, in which the diverse diet was initiated between 6 and 8 months and maintained stably afterwards, and children who deviated from this optimal pattern experienced a slower linear growth and weight gain. These findings were supported by observations presented in Chapter 5, in which mothers attributed the changes in child eating patterns to the seasonality of food supply and changes in children's eating mood and appetite. Many mothers

reflected that they were not able to provide fruits or meat regularly to their children during off-seasons, when fruit trees had not reached the stage of bearing fruits, or during lean season, when family incomes were not sufficient to acquire meat or fruits from the markets. Several mothers also explained that their children's appetite, eating mood and eating preferences varied from day to day and changed as children grew older, and most mothers had difficulties in adapting to these changes and ensuring their children eating a diverse food. While seasonality of food supply has been assessed in a large body of literature (Bai et al., 2020; Bonuedi et al., 2021; Broaddus-Shea et al., 2018), few studies has explored other determinants of changes in diet quality such as child eating appetite, mood and preferences.

Chapter 4 adds to the body of literature on the relationship between proximity to fresh food markets and children's dietary diversity score. While the previous literature found that children living closer to food markets had more diverse diet (Headey et al., 2019; Hirvonen & Hoddinott, 2017; Hirvonen et al., 2017; Stifel & Minten, 2017), we here showed that this association was modest, which can be due to two reasons. First, proximity to food markets was related to the consumption of some but not all food groups. Specifically, only consumption of land meat and other fruits and vegetables were related to proximity to fresh food markets while the consumption of other food groups such as eggs, vitamin A fruits and vegetables, or fish and seafood were not. Second, the associations between market proximity and diet were non-significant for lower wealth tertiles, suggesting that children from the lower wealth tertile may not benefit from better proximity to food markets. These finding can be explained by several observations reported in Chapter 5. Specifically, mothers in the rural and semi-rural areas reported having access to a wide range of food sources, including their own home-grown food, food grown by neighbors, informal fresh food markets, mobile vendors and to the lesser extent food gathered from natural lakes and wild grown plants. Typically, mothers would purchase food from a variety of sources. For example, some mothers acquired leafy green vegetables from their own gardens or neighbors, poultry and eggs from their own garden, but fruits, fish and seafood from food markets. Furthermore, several mothers also indicated the lack of household income as a barrier to purchasing food from markets. Although findings in Chapter 5 were drawn from interviews with mothers in Vietnam, the setting with generally higher household income and living standards than Cambodia, these qualitative

insights strengthen the hypothesis that low-income households depend on a variety of food sources and face financial barrier in acquiring food outside home.

In Chapter 5, we also demonstrated that maternal food choice behaviors in Vietnam is the balancing act between their food choice intentions and the presence of food choice constraints. We found that mothers had dual intentions in feeding children nutritious, safe food to prevent illnesses and promote growth and satisfying children's food preferences to increase their eating enjoyment. These dual intentions were different from the emphasis on satiety discussed in the studies of child feeding in rural Ethiopia, Ghana and Tajikistan (Haileselassie et al., 2020; Klassen et al., 2019; Kukeba et al., 2021). While satiety was also discussed by participating mothers in our study, it was mentioned in relation to healthy eating and illnesses prevention. We also found that these intentions were rooted in mothers' innate desire to nurture children's healthy growth and happiness, and they were shaped by cultural food traditions that dictate what, where, when and how young children should be fed and the network of health and food information, such as media, advertisement and family members. Despite these intentions, mothers had to consider the opportunities and constraints in their immediate food environment. First, while food availability was not a concern due to the presence of many sources of food, food unaffordability was cited as a major barrier of food purchase, which often occurred when families experienced crop loss, engaged in competing expenses such as housing loans or lacked farming resources such as farming land or gardens. Second, many mothers also expressed concern of harmful chemicals in food such as pesticides, preservatives and additives but this concern seemed to interfere with mothers' purchase of specific fruits or vegetables such as tomatoes or apples but did not seem to affect mothers' purchase of meat. Lastly, many mothers had to modify their feeding choice and feeding styles based on their children's eating preferences for taste and texture such as sourness, sweetness, blandness, tenderness or crunchiness. In particular, many mothers perceived that their children disliked chewing or had chewing difficulties, and as result fed their children primarily meat broth and finely chopped meat and vegetables. To which extent mothers accommodated their children depended on children's mood and temperament, or the extent children were willing to compromise their preferences to cooperate with their mothers. These findings suggest that food refusal and pickiness may contribute to the lack of diverse, nutrient-rich food in children's

meals, in addition to other commonly known determinants in the literature such as poor maternal knowledge on child nutrition or limited household resources (UNICEF, 2020).

Table 8: Summary of key findings of the dissertation

What the literature says	What this dissertation adds
Delayed introduction of diverse diet is a problem in rural communities	Maintenance of diverse diet is also a problem in rural communities (Chapter 3)
Seasonal food access may contribute to fluctuation in household food security and child diet diversity	Changes in child appetite and eating mood may also contribute to the poor maintenance of diverse diet in children (Chapter 5)
Satiety is the primary food choice intention among rural mothers	Health and enjoyment are also primary concerns of mothers in rural, farming communities (Chapter 5)
Delayed introduction of diverse diet is due to the lack of nutrition knowledge among caregivers	It may also be due to children refusing textured food or food with certain tastes and flavors (Chapter 5)
There is no consistent evidence that living closer to food markets is associated with improved child dietary diversity	Living closer to food market is associated with higher child dietary diversity, but the magnitude is small, possibly because of high food cost and reliance on other food sources (Chapter 4)

6.2 Strengths and limitations

This dissertation employed novel approaches to address several knowledge gaps. First of all, we were able to integrate data from different categories (i.e., temporal data in Chapter 3, spatial data in Chapter 4 and qualitative data in Chapter 5) and across different levels in the food system framework (i.e., market data in Chapter 4 and household data in Chapter 3). This integration allowed us to explore different perspectives and uncover nuances about socioecological drivers of diet in early life. For example, spatial distribution of food markets showed in Chapter 4 indicated that food markets in remote geographical areas are not only fewer in number but also smaller in the number of vendors. We also learned from Chapter 5 that, according to participating mothers, smaller food markets also have shorter operating hours. These results suggest that households living in remote areas face multiple food access barriers, including a longer travel time to food markets, more restricted hours to visit food markets and fewer choice of fresh produce. Additionally, we also

found in Chapter 5 that many children were perceived as not liking to chew or having difficulty in chewing, which may explain the delayed feeding of textured, fresh healthy food such as fruits and vegetables. These findings are important as previous literature have attributed the delayed diverse diet to caregivers' misperceptions about egg, meat or vegetables causing stomach upset in young children (Alive & Thrive, 2010; Dickin et al., 2021). Children preference of food texture seems to be an important factor that merits further examination.

Secondly, we employed advanced statistical methods to minimize bias and random error. For example, in Chapter 3, we calculated conditional growth measures to capture the relative gain in weight and height not predicted by the previous weight and height (Horta et al., 2017). Conditional measures represent children's deviation from their expected size, calculated based on their own previous measures and the growth pattern in their population. By considering for previous measures, this approach addresses the issue of regression to the mean, a phenomenon in which extreme measurements approach closer to the population mean in subsequent measures. This approach also allows us to control for time-invariant factors that affect child growth such as road access, water and sanitation and livestock ownership, which were not collected in the study or not sufficiently measured using the study's covariates. In Chapter 4, we also employed regression calibration technique to account for the fact that geographical coordinates of the surveyed households were displaced randomly in the Demographic and Health Surveys (National Institute of Statistics et al., 2015). The consequences of this displacement procedure on random and systematic error of regression estimates have been discussed at length in the literature (Warren et al., 2016). By employing regression calibration method, we were able to partially control for these errors and improve the robustness of our results (Warren et al., 2016).

This dissertation is not without limitations. In preceding chapters, we have discussed several limitations specific to each research aim. Here, we summarize key limitations that pertain to more than one specific aim and may affect the interpretations and generalizability of our overall findings. These limitations are related to the comparability between different data sources, the validity of the key results, and their generalizability.

This dissertation takes advantage of existing data sources which came from different settings or populations. In particular, while the data of child temporal dietary patterns (Chapter 3) and maternal food choice behaviors (Chapter 5) came from research studies in northern Vietnam, we lacked large-scale data of fresh food markets in Vietnam. Although the Agriculture and Nutrition for Health (A4NH) program had taken a new initiative to collect data on both nutrition and food markets in Northern Vietnam, the sample size of children under five years of age was modest (n ~ 300) (Huynh et al., 2021), which prompted our decision to use data in Cambodia to inform our broader understanding of food markets and child diet. Although Cambodia generally has a lower living standard and higher prevalence of child malnutrition than Vietnam, the two neighboring countries shared commonalities in history, administrative structures, agriculture development and the dominance of informal food markets. Thus, findings about food markets in Cambodia can complement the understanding we gathered in Vietnam. Besides the differences in settings, our data sources also differ in the targeted age range. While our quantitative analyses reported in Chapter 3 and Chapter 4 included children aged between 6 and 24 months, our qualitative analysis (Aim 3) was carried out with mothers of children at a broader age range between 6 months and 6 years of age. As a result, we exercised caution when using observations found in the qualitative aim to explain or strengthen the findings in the quantitative aims. For example, we found that child eating mood and temperament in children aged 6 months to 6 years is a key influencing driver of maternal food choice and inferred that this factor contributes to the instability of diverse diet in the first two years. This inference is grounded in our understanding that the first two years is the period where children developed their food preference and eating skills, such as satiety responses, flavor sensation, chewing ability or hand-mouth coordination (Forestell, 2017; Gisel, 1991; Mennella & Beauchamp, 1997; Ventura & Worobey, 2013). Nevertheless, future mixed-method research that targets specifically children aged 2 years or younger is needed to confirm if eating behaviors are the major driver of temporal diet pattern in this age group.

There are also limitations to the validity of this research. For example, analyses presented in Chapter 3 employed a complete case analysis approach to enable the longitudinal tracking of diet over time. While this approach retained an overall sample of 781 children, several dietary pattern strata had a small sample size of

fewer than 100, which may lead to unstable estimate of strata-specific conditional growth and as a result bias the inference towards the null. Additionally, Children included in our analysis may differ from the birth cohort in some characteristics that modify the relation between diet and growth. However, we show that this likelihood is low because there were no differences in the baseline and birth characteristics between the sample of children included in this analysis and the sample of children who were not. Similarly, analyses presented in Chapter 4 are also prone to bias towards the null due to the random displacement of geographical coordinates of household survey clusters, which was implemented by the Demographic and Health Survey to protect confidentiality of respondents. We attempted to mitigate this bias by applying the regression calibration technique, which involves creating a large number of validation datasets by displacing the household survey clusters (which were already displaced) using the displacement protocol and then estimating the bias using these validation techniques. Prior simulation analyses have showed that this technique can improve the validity and precision of the statistical inferences, but it does not remove the bias completely (Warren et al., 2016). Lastly, the qualitative nature of the analyses presented in Chapter 5 also make it prone to personal bias and interpretation. The primary analyst, the lead researcher undertaking this dissertation research, is a public health researcher born and grew up in Vietnam and may had biased interpretations of the data. However, we engaged two analysts who were unfamiliar with the context and held regular debriefing meetings with the core team to minimize the influence of personal biases and to ensure that themes were grounded in the data.

This dissertation also has limited generalizability outside its settings. First, we found in Chapter 3 that young children aged 2 years or younger did not maintain their minimum diverse diet over time but we were unable to assess whether this phenomenon also applied to children older than 2 years of age. Although we found in Chapter 5 that mothers of children older than 2 years of age also concerned about day-to-day fluctuation of children's diverse diet, we did not quantitatively assess whether this fluctuation results in only slight variation in diet with minimal consequences on child health outcomes or significant variation in diet quality that may increase the risk of malnutrition. Second, our findings may not be generalizable to other rural settings such as South Asia and Africa, where rural food markets are sparser, subsistence farming is more common and

household food insecurity is higher. High food insecurity may lead to consistently low dietary diversity over time. Third, women in our study context take charges of food acquisition and make decisions about food purchase and meal-time dishes (after taking account food preferences of their spouses and children). Such gender role may increase mothers' autonomy in financial decision-making, including the prioritization of resources on children's nutrition and diet. In contrast, in other settings such as rural Bangladesh, men are responsible for making food purchases at the markets while women experience restrictions on physical mobility (Lee et al., 2022). The differences in women autonomy might influence maternal priorities, intentions and preferences in feeding children.

6.3 Public health implications

This dissertation makes several important contributions to future behavioral changes program and rural food policy that aim to improve diet quality in young children in settings similar to rural Vietnam and Cambodia, where food insecurity is low and rural development is taking place rapidly.

First, for program implementors who wish to improve child feeding in Vietnam, this dissertation demonstrates that mothers in this setting desire to nurture both healthy growth and eating enjoyment in their children. These intentions have been reported in studies of mothers in urban Nepal, urban Sri Lanka and rural Malawi, but these intentions differ from mothers' priorities to feed children starch food to improve satiety in several rural communities in Ethiopia, Ghana and Tajikistan (Haileselassie et al., 2020; Klassen et al., 2019; Kukeba et al., 2021). The dual intentions observed in our study need to be acknowledged, leveraged and carefully balanced when communicating nutrition advice. In the other words, mothers need child feeding advice and messages to improve not only the healthiness of the meal but also the enjoyment of eating. Furthermore, we also showed that children eating patterns and maternal choice of food and feeding styles varied to a large extent during the course of a day, whereby nutrient-rich, healthy food were emphasized during lunch and dinner but snack, commercial food and child preferences were prioritized during snacks and evening desserts. These observations emphasized the need to tailor feeding messages to specific eating occasions. For example, designing messages about what to feed children at which meal occasions, such as "*an*

egg after naptime" or "*no coke after dinner*" may be more specific and effective than a general messages of what to eat and avoid. Lastly, through this dissertation, we recommend future behavioral change programs to design explicit messages about giving animal-sourced food, fruits and vegetables between 6 and 8 months of age. Current programs have focused on messages surrounding giving solid food between 6 and 8 months of age (Dickin et al., 2021), but we showed in both of our quantitative studies in Vietnam and Cambodia that the majority of children aged 6 and 8 months were introduced solid food but not necessarily minimum diverse diet. Thus, explicit messages about giving animal-sourced food, fruits and vegetables between 6 and 8 months of age are needed. For example, messages such as "*start giving soft and smashed fruits and vegetables at 6 months of age*" or "*start mixing animal-sourced food such as egg and flesh meat in the solid foods at 6 months of age*" may be more effective and specific than "*start giving complementary food at 6 months of age*", which have been a standard complementary feeding indicator and messages used in IYCF programs (Dickin et al., 2021). Similarly, explicit messages about ensuring the minimum diverse diet over time may also warranted. Designing these messages require better evidence and understanding of responsive feeding and child eating behaviors, which are areas with limited evidence and understanding in the IYCF literature (Bentley et al., 2011; Dickin et al., 2021).

Second, for policy makers, this dissertation points to several aspects of food environment that need to be strengthened via deliberate policies. First, as discussed in Chapter 5, the presence of alternative food choice such as biscuits and sugar-sweetened beverages may interfere with children's consumption of healthy fresh food. While several mothers indicated their attempts to minimize children's consumption of packaged food, other mothers also perceived commercial food such as biscuits or sweets as healthy (or harmless) food for children. Second, findings from both Chapter 4 and 5 suggested the importance of diverse food environment to help mitigate the impact of food seasonality and ensure the stability of diverse diet. A diverse food environment may comprise other alternatives to acquire food, such as sufficient land to grow food, natural habitats for catching wild fish and wild plants or different types of food vendors that are heterogeneous in food price and food options. Such diverse, heterogenous food environment can enable mothers and caregivers optimize their food budget and secure nutritious fresh food during times of economic difficulties. Creating such a diverse food environment require deliberate policies to conserve wild food resources,

encourage communal garden and school garden initiates, support small-scaled farmers and strengthen the network of informal markets and mobile vendors.

Although this dissertation was carried out prior to the COVID-19 pandemic, the pandemic and its unprecedented consequences have strengthened the case to support a diverse, flexible and resilient food system to better withstand future pandemics. During the pandemic, lockdowns and restrictions have led to restrictions in movement of farm labor and farm inputs, disruptions in food supply chains, lower sale of agricultural produce and loss of jobs and livelihoods, which exacerbated all forms of malnutrition, including an addition of 3 million children stunted, 7 million children wasted and 3 billion people unable to afford nutritious, quality diet, most of whom reside in the poorest communities in LMIC (Carducci et al., 2021; Headey et al., 2020). Surveys with smallholding farming communities affected by COVID-19 in India and Kenya revealed that communities with access to diverse food environment such as agricultural land, communal gardens and wild food resources coped better with the pandemic (Ghosh-Jerath et al., 2022; Merchant et al., 2022). Situational analyses of global food price data and food value chains also echoed the support for diverse food environment, with a particular emphasis for a stronger local market chain and local food production through investment in small-sized food enterprises and local food procurement system (Carducci et al., 2021; Heck et al., 2020), which have to be coupled with improvement in sanitation infrastructure and hygiene practices among small-sized food handlers to prevent the spread of future zoonotic diseases. These investments on communities' food production and local food markets are in contrast to the current government strategies to modernize and formalize food value chain in Vietnam (MoIT, 2009), but they are essential to ensure the healthy nutrition for children, as discussed in this dissertation, while ensuring the resilience of vulnerable communities against future pandemics.

6.4 Future research

This dissertation proposes a novel methodological approach for future research of longitudinal dietary patterns while identifying key areas of research in the domain of child diet quality.

In this dissertation, we qualitatively assessed changes in minimum dietary diversity indicator over time to construct temporal dietary patterns. This approach is straight-forward in interpretation and does not require statistical assumptions and modeling as compared to existing methods commonly used for constructing temporal dietary patterns such as principal component analysis or latent class analysis. Our approach can be applied to assess temporal changes in other dietary indicators, such as women and household dietary diversity (Azene et al., 2021; Savy et al., 2006), food variety score (a count of food items out of all possible healthy food items eaten) (Hatløy et al., 1998; Steyn et al., 2006) or recently developed global diet quality score (a food-based metric consisting of 25 food groups, designed to predict both under- and overnutrition risks) (Sabri et al., 2021). Such approach is particularly desirable in settings where food supply or household food access fluctuates over the year or in programs targeting populations that experience significant dietary changes such as preschool ages, adolescents, pregnancy or patients.

More importantly, this research underscores the need for longitudinal research to assess the changes in child dietary quality and its determinants, including fluctuations in food supply in the food environment, variations in caregivers' food acquisition practices, and changes in child eating behaviors. Assessing these changes are crucial to improving child nutrition in rural communities in LMIC for two reasons. First, these communities face a higher risk of food production shocks due to climatic unpredictability (Buhaug et al., 2015), which may require caregivers to modify their food acquisition practices to adapt to the seasonal changes in food availability and affordability. Second, children in rural LMIC are also at higher risk of repeated infections due to poor maternal nutrition and close proximity to livestock that carry zoonoses, and infections and illnesses have been linked with poor appetite, sub-optimal eating behaviors and difficult feeding (Bentley et al., 1995; Brown et al., 1995). In the short-term, there is a need for a longitudinal, formative research that combines child feeding observation with in-depth interviews of caregivers to document changes in child eating behaviors, caregivers feeding behaviors and their food acquisition practices. In the long-term, a detailed, muti-level and longitudinal study is warranted to quantify the changes in food environment, household food purchase and consumption, caregiver feeding practices and child eating behaviors, and assess how these changes may be related to nutritional and health outcomes during and after childhood. Quantifying these

changes and their impact may help generate evidence and develop metrics needed to advocate for stable, consistent optimal diet throughout the early life.

6.5 Conclusions

Early childhood is a crucial life stage marked by immense physical, social and emotional development. Helping a child to eat well at this stage ensures their adequate nutrition and sets the foundation for her lifelong health, but many communities and families lack the resources or guidance to provide a healthy, diverse diet for their children. This dissertation is our attempt to better understand the dynamics of diet during early childhood and the complexity of the underlying drivers. We found that diet quality and eating patterns changes in the early life, which may be influenced by changes in food access, mothers' feeding styles and children's eating behaviors. One approach to ensure children maintain a healthy, diverse diet through the early childhood is to create a healthy, resilient food environment, characterized by diverse presence of food options, food retailers and other food sources such as community garden or wild food harvesting to buffer economic shock or harvest lost. For future research, adequate resource should be prioritized for longitudinal studies in LMIC to track child diet and nutrition from early to late childhood and its relation on subsequent growth and development outcomes.

6.6 References

Alive & Thrive. (2010). *IYCF practices, beliefs and influences in Tigray Region, Ethiopia*.

Azene, A. G., Aragaw, A. M., Wubetie, H. T., Wassie, G. T., Tsegaye, G. W., Derebe, M. A., & Mitiku, H. D. (2021). Dietary diversity among pregnant women and associated factors in Ethiopia: Systematic review and meta-analysis. *Plos One*, *16*(6), e0251906. https://doi.org/10.1371/journal.pone.0251906

Bai, Y., Naumova, E. N., & Masters, W. A. (2020). Seasonality of diet costs reveals food system performance in East Africa. *Science Advances*, *6*(49), eabc2162. https://doi.org/https://doi.org/10.1126/sciadv.abc2162

Bentley, M. E., Black, M. M., & Hurtado, E. (1995). Child-Feeding and Appetite: What Can Programmes Do? *Food and Nutrition Bulletin*, *16*(4), 1-9. https://doi.org/10.1177/156482659501600408

Bentley, M. E., Wasser, H. M., & Creed-Kanashiro, H. M. (2011). Responsive Feeding and Child Undernutrition in Low- and Middle-Income Countries. *The Journal of Nutrition*, *141*(3), 502-507. https://doi.org/10.3945/jn.110.130005

Bonuedi, I., Kornher, L., & Gerber, N. (2021). Agricultural seasonality, market access, and food security in Sierra Leone. *Food Security*. https://doi.org/https://doi.org/10.1007/s12571-021-01242-z

Broaddus-Shea, E. T., Thorne-Lyman, A. L., Manohar, S., Nonyane, B. A. S., Winch, P. J., & West, K. P., Jr. (2018). Seasonality of Consumption of Nonstaple Nutritious Foods among Young Children from Nepal's 3 Agroecological Zones. *Curr Dev Nutr*, *2*(9), nzy058. https://doi.org/10.1093/cdn/nzy058

Brown, K. H., Peerson, J. M., Lopez de Romaña, G., de Kanashiro, H. C., & Black, R. E. (1995). Validity and epidemiology of reported poor appetite among Peruvian infants from a low-income, periurban community. *Am J Clin Nutr*, *61*(1), 26-32. https://doi.org/10.1093/ajcn/61.1.26

Buhaug, H., Benjaminsen, T. A., Sjaastad, E., & Magnus Theisen, O. (2015). Climate variability, food production shocks, and violent conflict in Sub-Saharan Africa. *Environmental Research Letters*, *10*(12), 125015. https://doi.org/10.1088/1748-9326/10/12/125015

Carducci, B., Keats, E. C., Ruel, M., Haddad, L., Osendarp, S. J. M., & Bhutta, Z. A. (2021). Food systems, diets and nutrition in the wake of COVID-19. *Nature Food*, *2*(2), 68-70. https://doi.org/10.1038/s43016-021-00233-9

Dickin, K. L., Litvin, K., McCann, J. K., & Coleman, F. M. (2021). Exploring the Influence of Social Norms on Complementary Feeding: A Scoping Review of Observational, Intervention, and Effectiveness Studies. *Current developments in nutrition*, *5*(2). https://doi.org/https://doi.org/10.1093/cdn/nzab001

Forestell, C. A. (2017). Flavor Perception and Preference Development in Human Infants. *Annals of Nutrition and Metabolism*, *70(suppl 3)*(Suppl. 3), 17-25. https://doi.org/https://doi.org/10.1159/000478759

Ghosh-Jerath, S., Kapoor, R., Dhasmana, A., Singh, A., Downs, S., & Ahmed, S. (2022). Effect of COVID-19 Pandemic on Food Systems and Determinants of Resilience in Indigenous Communities of

Jharkhand State, India: A Serial Cross-Sectional Study. *Front Sustain Food Syst*, *6*, 724321. https://doi.org/10.3389/fsufs.2022.724321

Gisel, E. G. (1991). Effect of food texture on the development of chewing of children between six months and two years of age. *Developmental Medicine & Child Neurology*, *33*(1), 69-79. https://doi.org/https://doi.org/10.1111/j.1469-8749.1991.tb14786.x

Haileselassie, M., Redae, G., Berhe, G., Henry, C. J., Nickerson, M. T., Tyler, B., & Mulugeta, A. (2020). Why are animal source foods rarely consumed by 6-23 months old children in rural communities of Northern Ethiopia? A qualitative study. *Plos One*, *15*(1), e0225707. https://doi.org/https://doi.org/10.1371/journal.pone.0225707

Hatløy, A., Torheim, L. E., & Oshaug, A. (1998). Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. *Eur J Clin Nutr*, *52*(12), 891-898. https://doi.org/10.1038/sj.ejcn.1600662

Headey, D., Heidkamp, R., Osendarp, S., Ruel, M., Scott, N., Black, R., Shekar, M., Bouis, H., Flory, A., Haddad, L., & Walker, N. (2020). Impacts of COVID-19 on childhood malnutrition and nutrition-related mortality. *The Lancet*, *396*(10250), 519-521. https://doi.org/10.1016/S0140-6736(20)31647-0

Headey, D., Hirvonen, K., Hoddinott, J., & Stifel, D. (2019). Rural Food Markets and Child Nutrition. *American Journal of Agricultural Economics*, *101*, 1311-1327. https://doi.org/https://doi.org/10.1093/ajae/aaz032

Heck, S., Campos, H., Barker, I., Okello, J. J., Baral, A., Boy, E., Brown, L., & Birol, E. (2020). Resilient agri-food systems for nutrition amidst COVID-19: evidence and lessons from food-based approaches to overcome micronutrient deficiency and rebuild livelihoods after crises. *Food Secur*, *12*(4), 823-830. https://doi.org/10.1007/s12571-020-01067-2

Hirvonen, K., & Hoddinott, J. (2017). Agricultural production and children's diets: evidence from rural Ethiopia [https://doi.org/10.1111/agec.12348]. *Agricultural Economics*, *48*(4), 469-480. https://doi.org/https://doi.org/10.1111/agec.12348

Hirvonen, K., Hoddinott, J., Minten, B., & Stifel, D. (2017). Children's Diets, Nutrition Knowledge, and Access to Markets. *World Development*, *95*, 303-315. https://doi.org/https://doi.org/10.1016/j.worlddev.2017.02.031

Horta, B. L., Victora, C. G., de Mola, C. L., Quevedo, L., Pinheiro, R. T., Gigante, D. P., Motta, J., & Barros, F. C. (2017). Associations of Linear Growth and Relative Weight Gain in Early Life with Human Capital at 30 Years of Age. *J Pediatr*, *182*, 85-91.e83. https://doi.org/10.1016/j.jpeds.2016.12.020

Huynh, T. T. T., Pham, H. T. M., Trinh, H. T., Duong, T. T., Nguyen, T. M., Hernandez, R., Lundy, M., Nguyen, K. T., Nguyen, L. L. T., Vuong, V. T., H.T., N., Truong, M. T., Do, H. P. T., Ranneri, J., HongKy, T., & de Haan, S. (2021). *Partial food systems baseline assessment at the Vietnam benchmark sites*.

Klassen, A. C., Milliron, B. J., Suehiro, Y., Abdulloeva, S., Leonberg, B., Grossman, S., Chenault, M., Bossert, L., Maqsood, J., Abduzhalilov, R., & Iskandari, M. (2019). "Then you raise them with Shirchoy or cookies": Understanding influences on delayed dietary diversity among children in Tajikistan. *Maternal & Child Nutrition*, *15*(2), e12694. https://doi.org/https://doi.org/10.1111/mcn.12694

Kukeba, M. W., Fallon, D., & Callery, P. (2021). Child feeding in rural northern Ghana: Carer's perceptions of food and their children's diets [https://doi.org/10.1111/mcn.13085]. *Maternal & Child Nutrition*, *17*(2), e13085. https://doi.org/https://doi.org/10.1111/mcn.13085

Lee, H. B., McNamara, P. E., & Bhattacharyya, K. (2022). Does linking women farmers to markets improve food security? Evidence from rural Bangladesh. *Agriculture & Food Security*, *11*(1), 33. https://doi.org/10.1186/s40066-022-00373-6

Mennella, J. A., & Beauchamp, G. K. (1997). Chapter 6 - The Ontogeny of Human Flavor Perception. In G. K. Beauchamp & L. Bartoshuk (Eds.), *Tasting and Smelling* (pp. 199-221). Academic Press. https://doi.org/https://doi.org/10.1016/B978-012161958-9/50007-5

Merchant, E. V., Fatima, T., Fatima, A., Maiyo, N., Mutuku, V., Keino, S., Simon, J. E., Hoffman, D. J., & Downs, S. M. (2022). The Influence of Food Environments on Food Security Resilience during the COVID-19 Pandemic: An Examination of Urban and Rural Difference in Kenya. *Nutrients*, *14*(14). https://doi.org/10.3390/nu14142939

MoIT. (2009). *Overview of the current status and direction of economic and social development in Hanoi in 2010, with a vision to 2030*.

National Institute of Statistics, Directorate General for Health, & ICF International. (2015). *Cambodia Demographic and Health Survey 2014*.

Sabri, B., Walter, W., & Megan, D. (2021). *Developing and validating a food-based global diet quality score* (Sight and Life report, Issue.

Savy, M., Martin-Prével, Y., Traissac, P., Eymard-Duvernay, S., & Delpeuch, F. (2006). Dietary Diversity Scores and Nutritional Status of Women Change during the Seasonal Food Shortage in Rural Burkina Faso. *The Journal of Nutrition*, *136*(10), 2625-2632. https://doi.org/10.1093/jn/136.10.2625

Steyn, N. P., Nel, J. H., Nantel, G., Kennedy, G., & Labadarios, D. (2006). Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Nutrition*, *9*(5), 644-650. https://doi.org/10.1079/PHN2005912

Stifel, D., & Minten, B. (2017). Market Access, Well-being, and Nutrition: Evidence from Ethiopia. *World Development*, *90*, 229-241. https://doi.org/http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129406

UNICEF. (2020). *UNICEF's Conceptual Framework on the Determinants of Maternal and Child Nutrition*.

Ventura, Alison K., & Worobey, J. (2013). Early Influences on the Development of Food Preferences. *Current Biology*, *23*(9), R401-R408. https://doi.org/10.1016/j.cub.2013.02.037

Warren, J. L., Perez-Heydrich, C., Burgert, C. R., & Emch, M. E. (2016). Influence of Demographic and Health Survey Point Displacements on Distance-Based Analyses. *Spatial Demography*, *4*(2), 155-173. https://doi.org/https://doi.org/10.1007/s40980-015-0014-0