INVESTIGATING THE CAUSES OF CHILD UNDERNUTRITION AND POOR DEVELOPMENT IN VAKINANKARATRA, MADAGASCAR: A MIXED-METHODS STUDY

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Submitted to the Faculty of the
Graduate College of the
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in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 2020

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ACKNOWLEDGEMENTS

"Mahay ny zavatra rehetra aho ao amin'Ilay mampahery ahy."
Filipiana 4:13
(I can do all things through Him who strengthens me)

I am grateful for God Almighty's love and abundant blessing that guided me throughout this journey.

I would like to gratefully acknowledge my Advisor and Mentor Dr. Barbara J. Stoecker, for her insightful guidance, her unfailing support, and her exemplary dedication to help her students. I am also grateful to my other committee members Dr. Gail Gates, Dr. Deana Hildebrand, Dr. David Thomas, and Dr. Fanjaniaina Fawbush-Razafimbelo for their continuing support, shared expertise, and encouragements.

I am thankful for the Regional Nutrition Office of Vakinankaratra for their support. I would like to acknowledge particularly the community nutrition agents and the field monitors in each of the fokontany we visited for their help during data collection. I am also thankful for my data collection team and my research assistants.

I am grateful to all the parents and their young children for their patience and their cooperation and for agreeing to be part of this study.

I am also very grateful for my family back in Madagascar (Neny, Heritiana sy Njiva, Harivola, Tsanta sy Hary) for their full support throughout my studies. Even thousand miles away from them, I have always felt their unwavering support and encouragements.

I also appreciate all of the Nutritional Sciences Department faculty and staff for creating a welcoming environment for learning and growth to all of the students.

I also would like to thank my friends back in Madagascar as well as my friends here in the US for their support. I also thank all the colleagues in Dr. Stoecker's lab for their help and their encouragements.

God bless you all!

Name: HASINA RAKOTOMANANA

Date of Degree: JULY, 2020

Title of Study: INVESTIGATING THE CAUSES OF CHILD UNDERNUTRITION AND POOR DEVELOPMENT IN VAKINANKARATRA, MADAGASCAR: A MIXED-METHODS STUDY

Major Field: NUTRITIONAL SCIENCES

Abstract:

The Vakinankaratra region of Madagascar has the highest burden of child undernutrition in the country. The purpose of this study was to investigate the factors associated with child undernutrition and to assess child development among children aged 6 to 23 months using a mixed-methods approach. Individual interviews (n = 8) and focus group discussions among fathers and mothers (10 with 63 total participants) were conducted. A sample of 391 mother-child dyads were included in the surveys and anthropometric measurements. Stunting rates were very high (69.4%) and 23.4% were underweight. Proportions of children achieving minimum dietary diversity (MDD) (35.8%) and consuming iron-rich foods (14.1%) were very low. Maternal knowledge of child feeding was associated with better feeding practices [Adjusted odds ratio: 1.2 (1.1 – 1.4)] for MDD. Consumption of iron-rich foods was significantly associated with lower odds of underweight [AOR: 0.3 (0.1 – 0.7)]. Barriers to optimal feeding practices included beliefs regarding certain foods considered as heavy, food insecurity, and heavy workload. Enablers include perceived benefits of appropriate complementary foods and positive relationships between the mothers and the community nutrition agents. Strong traditional gender roles around child care were a salient theme throughout the qualitative data as mothers were considered the primary child care providers. Fathers actively involved in child care activities would be ridiculed by the community and their wives would be considered lazy or unable to take care of their children. Besides providing for their families, fathers were also involved in home stimulation activities and support their wives with household chores when they were unavailable. Work conditions, separation and distance and reluctance prevented fathers from being more involved. Both fathers and mothers expressed interest in engaging fathers more in child care. Higher birthweight predicted increased length (ß = 0.11), weight (ß = 0.18), and weight-for-length (ß = 0.13). Higher maternal height predicted increased both length (ß = 0.17) and weight (ß = 0.16), while larger household size was associated with lower length (ß = -0.10) and weight (ß = -0.16). Using the Bayley's scale, children aged 11 – 13 months had low cognitive, motor, language, and socioemotional development scores.

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CHAPTER I

INTRODUCTION

Despite the decrease in stunting and wasting rates in children under 5 globally from 2000 to 2018 [1], child undernutrition is still a public health concern for several countries, especially in the African and South Asia regions. The number of children affected by undernutrition actually increased by 8.5 million in Africa from 2000 to 2018 [2]. According to this trend, reducing by 40% the number of stunted children as per the World Health Assembly (WHA) 2025 [3] target is very unlikely [4].

Madagascar is among the countries with the highest burden of child undernutrition. According to the latest data from the Multiple Indicator Clusters Surveys (MICS) conducted in 2018, 42% of the Malagasy children under 5 were stunted, 26% were underweight and 6% were wasted [5]. Particularly, the highlands comprised of the regions Analamanga, Vakinankaratra, Amoron'I Mania, and Haute Matsiatra all have stunting rates above 48%, higher than the national average. The Vakinankaratra region has the highest stunting (60%) and underweight (40%) rates in the country despite being one of the most agriculturally productive. The region is prosperous for many types of agricultural crops because of its volcanic soils and its climate.

In fact, Vakinankaratra has been the first in rice and maize production since 2013, and the dairy industry is also concentrated in that region. Despite this intriguing situation, there has been little attention to investigate why a highly productive region has such high rates of undernutrition.

Reduction and prevention of child undernutrition requires a strong political commitment and effective evidence-based nutrition interventions, but most importantly local context should be considered [6]. Further analysis of the 2009 Madagascar Demographic and Health Survey showed that region of residence is a basic factor for stunting, suggesting that nutrition actions should be tailored to each regional context [7]. In addition, intervention timing is crucial as the first two years of life offer a unique window of opportunity to prevent growth faltering [8]. Concurrent to the rapid growth during that period, important processes required for development are also occurring [9, 10]. Adequate nutrition and appropriate stimulation are needed to ensure optimal growth and promote child development. If any one of these conditions is not met, children will be less likely to achieve their full potential. Identifying the factors that influence child growth and development during the first two years in the context of the Vakinankaratra region will provide valuable insights for future interventions.

Furthermore, there is accumulating evidence that involving other household members in child care activities, including feeding, has positive results on child nutrition outcomes [11, 12]. Particularly, the potential of engaging fathers more in child care and feeding has been explored in several low- and middle-income countries with promising results [13, 14]. However, in countries with conservative values such as Madagascar, involving fathers in child care would require extensive preliminary research to explore the individual, cultural, and social factors. Knowing the attitudes and beliefs as well as the perception of the community will likely help in designing culturally appropriate and effective interventions that will engage fathers in child care activities.

For the Vakinankaratra region to be on track to reduce its child undernutrition rates in line with the World Health Assembly (WHA) target of 2025, evidence-based, innovative, as well as culturally and context appropriate interventions and policies should be implemented. Therefore, the purpose of this study is to 1) investigate the factors associated with child undernutrition and its association with poor development in Vakinankaratra region of Madagascar; and 2) to explore the attitudes of parents and the community regarding fathers' involvement in child care.

The objectives of the study were:

- To evaluate maternal knowledge and practices of complementary feeding and their association with child undernutrition risk
- To assess the barriers and enablers of appropriate complementary feeding practices
- To assess the community's perceptions and the barriers of fathers' involvement in child care
- To analyze the predictors of child growth in a high stunting area of Madagascar
- To assess the development of a subsample of children aged 11 – 13 months and its association with child nutrition in the Vakinankaratra region

Significance of study

There is limited literature on child undernutrition in Madagascar; specifically, studies evaluating the factors contributing to child growth in the Vakinankaratra region are lacking. Additionally, the interplay between child nutrition and child development has not been explored in the region. This study addressed this evidence gap by investigating the associations between complementary feeding knowledge and practices and child undernutrition in a region with high stunting and underweight rates. Other immediate and underlying factors of child undernutrition also

were explored. Results of this study will be helpful in designing and implementing context-specific and more effective nutrition interventions.

Because fathers' involvement has the potential to contribute to the reduction of child undernutrition and the promotion of child development, the attitudes and perceptions of the community regarding this topic were assessed using qualitative methods. The use of a mixed-methods approach allows for a more comprehensive assessment of the child undernutrition situation in the region and the influence of different factors at the child, household, and community levels.

Limitations

- Because of the cross-sectional design of the study, no causation can be inferred based on the results. However, appropriate statistical control of potential confounding variables strengthened the reliability of the results.

- Data were collected only from communities covered by the national community nutrition program (*Programme National de Nutrition Communautaire* or PNNC) with Community Nutrition Agents (CNAs). Also, although randomly selected, certain communes (8 of 32) and fokontanys (10 of 84) that were hard to reach because of poor road conditions or very long distance from the main town (more than 2 hours walk) were excluded. These may have reduced the representativeness of the sample. The eliminated communes and fokontanys were replaced by the next commune or fokontany on the randomization list.

- Limitations pertaining to questionnaire-based studies are acknowledged: social desirability and recall bias from the participants.

- Data collection occurred while some communities were harvesting rice while others were still in the lean season, which could influence the dietary pattern of households and children. Food would

be more available and affordable for communities in which harvest season had begun compared to those still in the lean season.

- Child development assessment was conducted the same day as the anthropometric measurements. Some children were still upset from the measurements and were not engaging. Efforts were made to allow the child to be comfortable before any test.

CHAPTER II

REVIEW OF LITERATURE

1. Child undernutrition

Undernutrition occurs when the nutritional needs of the child are not met. This can result in a wide range of disorders that can be classified into two categories: growth faltering and micronutrient deficiency [15]. Growth impairment is assessed by comparing the child's height or length and weight to a reference population that has healthy growth [16, 17]. The difference between the median of the reference population and the child's anthropometrics is called z-score and is adjusted for age and sex. The height/length-for-age z-scores (HAZ or LAZ), weight-for-age z-scores (WAZ) and weight-for-height/length z-scores (WHZ or WLZ) are then the variables used in studies and programs to assess child growth. Children with z-scores lower than -2 are considered stunted if they are too short for their age (HAZ or LAZ < -2) according to the 2006 WHO Growth Standards. The same cutoff is used to determine underweight (WAZ < -2) and wasted children (WHZ or WLZ < -2) [18].

Vitamins and minerals are essential nutrients that are required for various metabolic processes. Although small quantities are needed daily, deficiencies in micronutrients result in serious health damages that can be permanent, especially in children. The first four nutrition

priorities identified by WHO as problematic in several parts of the world are: protein/energy, vitamin A, iron, and iodine.

If not corrected early enough, child undernutrition can lead to severe negative consequences in the short and in the long term at both the individual and the community level. Undernourished children are more vulnerable to infections such as pneumonia and diarrhea due to their weakened immune system [19]. In return, these infections can exacerbate nutritional deficiencies because nutrients are diverted from growth [20-22]. Also, stunted and severely wasted children have a higher mortality risk. Globally, an estimated 21.4% of deaths in children under five are directly attributed to stunting, severe wasting, and intrauterine growth restriction [23]. In addition, nutritional deficiency early in life negatively affects brain development ultimately leading to poorer cognitive and impaired motor and socioemotional development [19, 24, 25]. Stunting has been identified as a major risk factor for impaired child development in countries with high burdens of malnutrition [9]. As a result of undernutrition, children tend to have less schooling and lower academic performance [26].

Child undernutrition also has long lasting impact on individuals and the community. Follow-up studies from the Institute of Nutrition of Central America and Panama (INCAP) Oriente longitudinal study [27] in Guatemala showed that better nutrition in infancy resulted in higher wages in adulthood [28]. Similar findings were reported from Brazil where each unit increase of length-for-age z-score in children under five was associated with a 8% increase in income [26]. Undernourished children are also more likely to have lower productivity, most probably due to lower lean body mass especially in activities requiring physical labor [19, 28]. In addition, nutritional deprivation in utero and during childhood may increase the risk of chronic diseases in adulthood especially in the case of rapid weight gain [26, 29].

Finally, the negative consequences of child undernutrition can carry over to the next generation as short stature mothers are more likely to give birth to low birthweight infants who are at a greater risk of being stunted [19, 26]. This intergenerational effect of undernutrition is also likely to reinforce the vicious cycle of poverty.

In summary, inadequate nutrition during childhood negatively impacts not only the child's health in the short term but also the economic productivity and even their offspring in the long term. This is the main reason why height-for-age at two years is often cited as the best predictor of human capital [26].

2. Nutrition before and during the first two years

To prevent these negative long-term consequences and to promote child growth, it is necessary to break the cycle of undernutrition. The first thousand days, from conception until the second birthday, offer a unique window of opportunity to correct growth faltering and to promote child development during which nutrition plays a critical role [30].

Preconception

There is evidence that nutrition's influence on child growth even starts before conception [31]. Data from the PRECONCEPT trial in Vietnam showed that higher maternal weight before conception was positively associated with birthweight. Also, women who were in the lowest tertile of maternal weight (< 43 kg) were more likely to have small for gestational age infants [adjusted odds ratio AOR = 2.9 95% CI (1.9 – 4.5)] and to give birth to low birthweight infants [AOR = 3.1 (1.5 – 6.2)]. Low maternal pre-pregnancy weight (< 43 kg) was still a risk factor for child stunting at two years in the same population [32]. Maternal height, which may be limited by

chronic undernutrition, has been shown consistently to be positively associated with child growth. A pooled analysis from 109 Demographic and Health Surveys (DHS) reported that even a 1 cm increase in maternal height was associated with lower risks of child mortality (relative risk RR = 0.9), child stunting (RR = 0.9), and wasting (RR = 0.9) [33].

Pregnancy

Maternal nutrition during pregnancy is vital for fetal growth as it is estimated that 20% of stunting begins in utero [34]. Inadequate weight gain and nutritional imbalance during pregnancy hinders child growth and can lead to negative birth outcomes. For example, folate deficiency can result in neural tube defects [35, 36], severe iodine deficiency can cause cretinism in infants [37, 38] and excess vitamin A intake may be teratogenic [39]. Pregnant women also have higher energy and protein needs compared to non-pregnant women [40]. Preventing low birthweight (LBW) and small-for-gestational age (SGA) births is then important as both are major risk factors for child undernutrition. In a pooled analysis of 19 longitudinal studies, LBW infants were more likely to be stunted [AOR = 2.92 (2.56 – 3.33)], underweight [(AOR = 3.48 (3.14 – 3.987)], and wasted [AOR = 2.68 (2.23 – 3.21)] at 12 to 60 months [34]. Infants who were SGA also had similar increased risk: AOR = 2.32 (2.12 – 2.54) for stunting, AOR = 2.96 (2.61 – 3.36) for underweight, and AOR = 2.36 (2.14 – 2.60) for wasting. Also, infants who were both LBW and SGA had even higher risks of stunting as well as an increased risk of mortality [41, 42].

Infancy

For the first half of the first postnatal year, breast milk contains the necessary nutrients to meet the needs of the rapidly growing infant. Infants' nutritional needs are high compared to their body size; also, their digestive system is not mature yet to process other forms of food, making

breast milk the ideal source of nutrients for infants [40]. During lactation, milk production is prioritized at the expense of maternal nutrient reserves. The composition of breast milk is then relatively stable and does not change drastically. However, lipid and protein content decrease slowly over time and micronutrient composition is influenced by maternal diet and nutritional status [43-45]. Water-soluble vitamins, except folate, and fat-soluble vitamin concentrations along with iodine and selenium depend on maternal diet [45]. Breast milk also contains a multitude of bioactive components and immunological factors that are beneficial for the infant's health and development [44].

In addition, early initiation of breastfeeding within the first hour after birth has been shown to decrease neonatal mortality risks [46]. Moreover, exclusive breastfeeding has been shown to reduce all-cause mortality in infants 0-5 months [47]. Compared to exclusively breastfed infants, predominantly breastfed [RR=1.48 (1.14-1.92)], partially breastfed [RR=2.84 (1.63-4.97)], and non-breastfed infants [RR=14.4 (6.13-33.9)] all had higher risks of mortality. There appears to be a dose-response effect of breastfeeding practices and risk of mortality. The risks of infection-related illness followed a similar trend in infants 6-23 months. A systematic review of studies from low- and middle-income countries (LMICs) also reported the protective effects of breastfeeding against diarrhea and pneumonia [48].

In the long-term, breastfeeding may improve cognition. Results from a meta-analysis reported higher mean cognitive development scores in children and adolescents who were breastfed [mean difference of intellectual quotient (IQ) = 3.44 points (2.30-4.58)] compared to those who were not breastfed, even after adjustment with maternal IQ [49]. Breast milk not only provides adequate nutrition during the first six months but also it provides protection against infections and, in the long-term, can improve cognition. For all these reasons, the WHO and UNICEF recommend that infants be breastfed during the first hour of life, and that they be exclusively breastfed during the first six months whenever possible. Also, infants should be

introduced to adequate complementary foods at six months while continuing breastfeeding up to two years or beyond [50].

Starting from six months, breast milk is no longer sufficient to meet the nutritional needs of the growing infant. For example, infants aged 6-8 months need an average of 200 kcal per day in addition to breast milk and the gap to be filled by complementary foods increases with age. For children 12-23 months, approximately 550 kcal/day needs to come from foods [51]. The case is similar for almost all nutrients; in fact, infants have higher nutrient requirements relative to their body size compared to adults. Certain nutrients such as zinc and iron become insufficient to meet the high nutritional needs of the infants because of their low concentration in breast milk [51, 52]. Thus, the nutrient provided by breast milk need to be supplemented from foods, which puts infants at a high risk of micronutrient deficiency especially if complementary feeding is inadequate or introduced late [43]. A challenge in complementary feeding is that because of their smaller stomach capacity, infants have to eat nutrient-dense foods with adequate energy and micronutrient intake. Consequently, they need to be fed a variety of foods more frequently. However, in LMICs, complementary foods are often based on staple foods and not diverse [52]. Globally, only 29.4% of 6-23 months infants met the minimum dietary diversity based on the WHO 2008 indicators, meaning that they ate from at least four food groups [53]. Complementary foods given to infants are often not nutritionally adequate, especially for micronutrients, increasing their risks of undernutrition. Pooled data from 39 countries showed significant increased odds of stunting of 1.39 in infants aged 6-11 months who did not eat animal-source foods (ASF) compared to infants who received ASF [54]. In addition, global growth trajectory of infants from birth shows that LAZ, WAZ, and WLZ all drop from 6 months [55, 56]. WLZ and WAZ increase and stabilize at 24 months but LAZ continues to drop throughout the first two years of life. These data suggest the risk of being stunted, underweight, and wasted are very high

starting from 6 months globally, which coincides with the time of introduction of complementary feeding.

In summary, the first two years of life is characterized by high nutritional demands that must be met in order to promote optimal growth. This period also provides an opportunity for interventions to address undernutrition due to rapid growth. Although catch up growth is possible beyond the first two years [57], the consequences of undernutrition during that critical period are likely to be permanent.

3. Complementary feeding practices

Due to the vital importance of nutrition on health and development during early life, reliable and easy to assess indicators of feeding and nutrition are required. The most widely used in both research and program evaluation are the WHO Infant and Young Child Feeding (IYCF) indicators issued in 2008 [58]. The IYCF indicators are based on a 24-hour food list from the mother or the primary caregiver of the child and can be incorporated easily as part of a survey questionnaire. This set of population-level indicators assesses both breastfeeding and complementary feeding practices up to 23 months (Appendix 1). There are 5 indicators to assess complementary feeding practices in children aged 6-23 months: introduction of solid, semi-solid and soft foods, minimum dietary diversity, minimum meal frequency, minimum acceptable diet, and consumption of iron-rich and iron-fortified foods. Results are expressed as proportions of infants who met specific requirements for each indicator.

Introduction of solid, semi-solid and soft foods

Infants should be given complementary foods from 6 months and no later than 8 months [59]. The infant will be developmentally ready to eat and swallow food other than breast milk, and the digestive system should be mature enough as well at that age [43, 59]. If introduced early, inadequate complementary foods may displace certain nutrients that would have been provided by breast milk, which will increase the risk of deficiency. Additionally, if complementary foods are not prepared safely, they can be contaminated and cause infections such as diarrhea. If introduced later than 8 months, there is a high risk of nutrient deficiency as breast milk can no longer provide adequate nutrients at that age.

Minimum dietary diversity (MDD)

The MMD indicator is a proxy for the micronutrient adequacy of the child's diet. Foods consumed by the child the previous day are categorized into 7 food groups: grains, roots and tubers, legumes and nuts, dairy products, eggs, flesh foods (meat, fish, poultry, organ meat), vitamin A-rich fruits and vegetables, and other fruits and vegetables. With a score of 4 or higher, a child has a high likelihood of having eaten at least one fruit or vegetable and at least one animal-source food in addition to the staple food, and thus considered to meet the MDD.

Minimum meal frequency (MMF)

The MMF captures the quantity of complementary food and is used as a proxy for energy intake. The caregiver is asked how many times the child ate the previous day. Very thin, watery soups and liquids are not included in this indicator because of their low caloric content, otherwise, snacks and all the other foods are included. A breastfed 6 – 8 months child will meet

the MMF by eating 2 times a day. The minimum is 3 times per day for a breastfed 9 – 23 months child, and 4 times per day for non-breastfed children.

Minimum acceptable diet (MAD)

MAD is a composite indicator measuring both the quality and the quantity of complementary foods. A child will meet the MAD only by achieving both the MDD and the MMF.

Consumption of iron-rich or iron-fortified foods

This indicator assesses adequacy of iron intake, which is a problem nutrient starting at around 6 months when the infant's body stores may be depleted. Then, iron has to be supplied from other sources, mainly complementary foods such as meat, organ meat, poultry and fish. Consumption of iron-fortified foods specifically designed for infants and young children and addition of micronutrient powders are also included in this indicator.

With these indicators capturing key dimensions of the recommended complementary feeding of the breastfed child, it is expected that they should predict child growth very well. However, studies that investigated the association between IYCF indicators and child anthropometrics in LMICs reported mixed results and associations were not always statistically significant (Table II.1).

Table II.1. Summary of associations between the infant and young child feeding (IYCF) practices and child nutritional status

IYCF indicator	Country (reference)	LAZ[1]	WAZ[1]	WHZ[1]	Stunting[2]	Underweight[2]	Wasting[2]
Timely introduction of complementary foods	Pooled data from 14 countries [60]	-	-	-	0.5 (0.41-0.6)	0.52 (0.44-0.62)	-
	Ethiopia [61]	NS	NS	NS	-	-	-
	Zambia [61]	1.19	NS	-0.94	-	-	-
	Zambia [62]	1.19	NA	-0.94	NS	-	NS
Minimum diet diversity	Pooled data from 14 countries [60]	-	-	-	0.79 (0.72-0.86)	0.74 (0.66-0.84)	-
	Ethiopia [61]	NS	0.37	NS	-	-	-
	Zambia [61]	0.23	NS	NS	-	-	-
	Zambia [62]	0.23	-	NS	Ns	-	NS
Minimum meal frequency	Pooled data from 14 countries [60]	-	-	-	NS	NS	NA
	Ethiopia [61]	NS	NS	NS	-	-	-
	Zambia [61]	NS	NS	NS	-	-	-

	Uganda [63]	-	-	0.21	NS	NA	0.61 (0.38-0.99)
	Malawi [64]	-	-	-	NS	0.41 (0.21-0.79)[3]	NS
Minimum acceptable diet	Pooled data from 14 countries [60]	-	-	-	0.87 (0.79-0.95)	0.85 (0.77-0.94)	NS
	Ethiopia [61]	0.43	0.48	NS	-	-	NA
	Zambia [61]	0.27	0.17	NS	-	-	NA
	Zimbabwe [62]	-	-	NS	0.55 (0.31-0.97)	NS	2.85 (1.11-7.3)
	Uganda [62]	NS	-	0.21	NS	-	NS
	Malawi [64]	-	-	-	NS	0.23 (0.08-0.65)[3]	NS
Consumption of iron-rich foods	Pooled data from 14 countries [60]	NS	NS	NS	0.82 (0.76-0.89)	0.83 (0.77-0.90)	-
	Ethiopia [61]	NS	NS	NS	-	-	-
	Zambia [61]	NS	NS	NS	-	-	-
	Malawi [64]	-	-	-	NS	NS	NS

All results were statistically significant with $p < 0.05$ and all models were adjusted for covariates

[1]Results expressed as ß coefficients from linear regression models

[2]Results are expressed with adjusted odds ratio AOR (95% confidence interval)

[3]Results for children aged 13-23 months

NS: not significant

LAZ: Length-for-age z-scores; WAZ: Weight-for-age z-scores; WHZ: Weight-for-height z-scores

The first and most cited critique regarding the WHO IYCF indicators is their lack of sensitivity and specificity [62, 65]. This is especially relevant for the MDD and the MMF. When counting the food groups, all foods should be considered regardless of their quantity, except for condiments. This can be an issue for mixed dishes with several ingredients but in small quantity. Also, when households do not cook separate foods for their infants, they usually mash portions of family foods that may or may not contain all the ingredients included in the original pot. These practices can result in an overestimation of the quality of the complementary foods. For the MMF, there is also the issue of what constitutes a meal and a snack, which may have different meanings in different contexts. Asking a caregiver how many times their child ate the previous day may lead to an inaccurate number of meals. Another weakness of the indicators is that they fail to capture long-term feeding practices due to the recall period of only 24 hours. Intake the previous day may not reflect the overall intake of the infant over a more representative period. And there is always the risk of recall bias and social desirability during surveys.

To address these weaknesses while keeping the convenience of the IYCF indicators, the WHO and UNICEF convened a meeting of experts in 2017 to discuss potential solutions [65]. A few options to change the assessment and the operational definition of MDD were suggested. The panel recommended adding a separate food group consisting of breast milk and infant formula to eliminate the advantage non-breastfed children had over their breastfed counterparts. Infant formula has been categorized in the dairy food group, thus non-breastfed children were only required to have three more food groups to achieve MDD compared to four for breastfed infants. With breast milk and infant formula forming their own group, a cut-off of 5 or more food groups is required to achieve MDD. Also, for mixed dishes, the expert panel suggested that only the main ingredients should be counted, except in case of a substantial mixed food, where all ingredients should be included. When possible, a minimum quantity of 10 grams can be applied for minor ingredients. No change was suggested for MMF to avoid confusion and complexity

during data collection and reporting regarding milk feeds in non-breastfed infants. And no change has been suggested to MAD, although the original operational definition was corrected. MAD should be a composite indicator for MAD and MMF for both breastfed and non-breastfed infants. Frequency of formula feeding was included in the calculation of MMF in the original IYCF indicator definition [58].

Despite their weaknesses, the IYCF indicators have also several strengths. They are simple and easy to use indicators that can be incorporated in large surveys to assess the feeding practices of a given population. They have been used to monitor the progress and trends of feeding practices at a national or regional level and even globally. In addition, the indicators can be used both in research and in programs. With that, the IYCF indicators can be used to target populations with suboptimal practices for interventions. For better results, questionnaires should be pilot tested and readjusted to adapt to the local context. Also, to capture the seasonality of feeding practices, the indicators should be assessed twice a year at different seasons, for example during harvest and lean seasons.

4. Hygiene and sanitation

Besides adequate diets, hygiene and sanitation are also critical for child growth. Poor water, sanitation, and hygiene (WASH) practices have been associated consistently with child undernutrition in global populations [66-68]. And, improved WASH practices generally have been associated with better child anthropometrics [21, 66, 67, 69, 70]. The link between poor WASH and child suboptimal growth may be explained through two main pathways: infections from microbial and helminth contamination and the change in the gut referred to as environmental enteropathy dysfunction (EED). Acute infections such as diarrhea and helminth contamination from inappropriate hygiene can impair nutrient absorption and ultimately reduce

growth velocity [22, 71, 72]. EED is a condition characterized by atrophy of the villi and systemic inflammation due to a constant exposure to pathogens in areas with poor WASH practices [73]. Infants affected with EED will then have reduced nutrient absorption that may lead to impaired growth. Moreover, the gut barrier function may also be altered causing the pathogens to translocate from the lumen, causing intestinal and systemic inflammation that will divert nutrient utilization from growth [20, 74, 75].

WASH practices can be assessed using the newly issued UNICEF and WHO Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) [76]. The indicators were updated to include more qualifications within each category, now called "ladders". For example, safe access and adequate quality drinking water should not only be protected from contamination but also should be available on premise. Besides the improved source of water, the next better ladder specifies that the time spent fetching water should also be less than 30 minutes including waiting in line. Table II.2 summarizes the specifications within each ladder of the WASH indicators. Similar to the IYCF practices, assessment of WASH practices using the JMP can be included in large scale surveys. Also, they can be used for both program monitoring and research studies.

Table II.2. The WHO and UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) criteria [76].

Ladder	Characteristics
WATER	
Surface water	River, dam, lake, pond, stream, canal, or irrigation canal
Unimproved	Unprotected dug well or unprotected spring
Limited	Improved source[1] and collection time exceeds 30 minutes
Basic	Improved source[1] and collection time is no more than 30 minutes for roundtrip
Safely managed	Improved source[1] and available on premises and available when needed and free from fecal and chemical contamination
SANITATION	
Open defecation	Disposal of human feces in fields, forests, bushes, open bodies of water, beaches and other open spaces, or with solid waste
Unimproved	Pit latrines without a slab, hanging latrines, or bucket latrines
Limited	Improved facilities[2] and shared between 2 or more households
Basic	Improved facilities[2] and not shared with other households
Safely managed (not included in analyses in this paper)	Improved facilities[2] and not shared with other households and extra excreta are safely disposed *in situ* or transported and treated off-site
HYGIENE	
No facility	No handwashing facility on premises
Limited	Handwashing facility on premises without soap and water
Basic	Handwashing facility on premises with soap and water

[1]Improved sources of drinking water include piped water, tube well, borehole, protected spring or protected well, rainwater, tanker truck, cart with small tank, or bottled water.
[2]Improved sanitation facilities include flush/pour flush, piped sewer system, septic tanks, pit latrines, ventilated pit latrines, composting toilets, or pit latrines with slab.

5. Other sociodemographic factors

Undernutrition is a multifactorial problem [4, 77, 78]. A multitude of factors at the child (immediate), household (underlying), and the community level (basic) have been shown to influence child growth after birth in countries with a high burden of child undernutrition (Figure II.1). Adequate dietary intake is a major contributor to child growth as nutrient deficiency will

lead to undernutrition. Other immediate factors include sex of the child as males often have increased odds of stunting compared to females [79]. Also, the risk of undernutrition increases with age in children under 5 years [55, 56]. Malnourished mothers are more likely to have undernourished children, especially in the case of stunting [23]. Immunization and health status in general are also immediate factors of child undernutrition [7, 80, 81]. The underlying factors of child undernutrition include household and parental factors. Household food insecurity, inappropriate feeding practices, poor hygiene and sanitation, and lack of access to health care have all been identified as risk factors for child undernutrition. These factors can be influenced by maternal and paternal education, occupation, and health-seeking behaviors [64, 82, 83]. Parental exposure to media is a determinant of feeding practices, and indirectly influence child growth [84, 85]. Media, including radio, posters, and billboards, are a communication channel for spreading nutrition information in various contexts. Media campaigns have been used in intervention studies to successfully improve breastfeeding and complementary feeding practices in different LMICs [86-88]. Poor maternal mental health has also been associated with suboptimal feeding practices and child growth [89, 90]. In addition, limited household wealth and poor status of women have been correlated to growth faltering [91]. Lastly, the basic causes of undernutrition include lack of human capital, overall poverty, and the lack of government commitment to implement and reinforce nutrition policies.

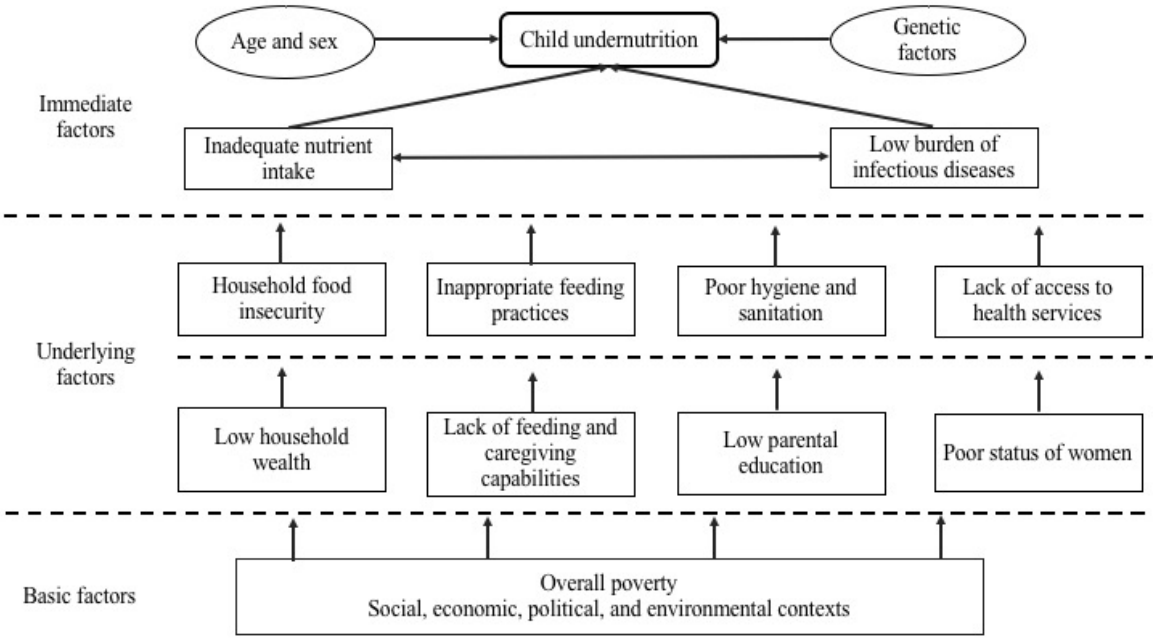

Figure II.1. Conceptual framework on child growth and associated factors. Adapted from Black *et al.* [77] and WHO [3].

6. Child development

Child development refers to a series of changes in various neurobehavioral aspects in infancy and childhood. During the early years, young children learn and show physical and mental abilities that are needed for productive and healthy adulthood. These abilities can be grouped in three main categories: physical development, cognitive development, and personality and social development [92]. Physical development includes changes in the brain, the muscular system, the senses and the motor skills [93]. Cognitive development involves learning processes, memory, and problem solving. Personality and social development include changes in interaction and communication with other people [92, 93]. The extent and the velocity of child development depends on individual factors such as appropriate brain development and genetics as well as

external factors such as optimal stimulation and household characteristics [94]. But also, nutrition during the early years can affect brain development and function.

Brain development and nutrition

The brain evolves from an undifferentiated to a more specified organ performing complex tasks [95]. Neuroplasticity refers to the brain's capacity to respond to environmental stimuli during its formation. As the brain evolves, it loses its plasticity over time. The first three years of life is an important period of brain plasticity. Neuroscientists introduced the terms critical and sensitive periods of brain development. Critical periods refer to determined epochs of development during which the brain's responses to environmental stimuli, including nutrition, become permanent, whether positive or negative. Sensitive periods extend longer meaning that the particular region of the brain is more receptive to stimuli over a longer period compared to its critical period. Each region of the brain has its own critical and sensitive periods and their nutrient requirements at any given time, but it is understood that they take place during the first three years. When all the conditions are not assembled, one of them being nutrient adequacy, brain formation will be hindered which ultimately will lead to impaired development later in life.

Brain development starts during the early stages of pregnancy and requires adequate nutrient input. Important processes that will determine future development such as myelination and synaptogenesis start *in utero* [9] and nutrient needs depend on the particular region of the brain at a given moment of its development. All nutrients are important for these processes during this period, but deficiency in protein and in long chain polyunsaturated fatty acids lead to potential permanent damages such as decreased brain size and lower number of neurons [10, 25]. Micronutrients including iron, iodine, folate, and zinc also play critical roles in the early stages of brain development *in utero*. Deficiency in these nutrients can lead to impairment in working

memory, and in cognitive and motor development of infants [24]. After birth, these nutrients continue to be critical in brain development throughout the first three years of life as the brain regions start to differentiate and to specialize. More complex domains of development such as visual function, receptive language and speech as well as higher cognitive functions all peak before the age of two. If this opportunity is missed, then infants will likely not attain their full development potential [9]. Due to their high postnatal needs for brain development, protein and iron are still important in infants and children and deficits may result in lower intellectual quotient (IQ), increased hesitancy, and slower motor development later in life [95].

Child growth and development

In addition to the key roles of individual nutrients, overall growth, particularly low birthweight [94] and linear growth during the first two years of life [96] have also been associated with development. Meta-analyses of observational and cohort studies from LMICs reported positive association between linear growth and cognitive and motor development in children [96]. The effect was greater for children under two. Cognition score would increase significantly by 0.24 (0.14-0.33) standardized mean difference (SMD) points compared to an increase of 0.09 SMD points (0.05-0.12) for each unit increase in LAZ. Motor development scores also increased by 0.38 (0.31-0.46) for each unit increase in HAZ. In Bangladesh, child length before the age of two also significantly predicted higher IQ scores at 64 months even after controlling for child home stimulation and socioeconomic status [97]. Similarly, the coefficients were greater for child length [β=0.11 (0.07-0.14)] at 0-12 months and [β=0.08 (0.04-0.12)] at 12-24 months, than for later growth [β=0.04 (0.005-0.08)] at 24-64 month. These data emphasize the importance of growth, and the factors that promote linear growth, during the first two years, on child development. Moreover, catch-up linear growth at five years may not necessarily lead to catch-up development. In a cohort study in South Africa, children who were stunted at age two but had

normal growth at age five still did not perform as well on cognitive tests as those who were not stunted at age two, even after controlling for confounders [98].

There is no definite conclusion on the mechanisms linking linear growth to child development. Stunting and impaired development have common risk factors such as poverty and certain micronutrient deficiencies, thus it is difficult to determine causal pathways. Nevertheless, a few mechanisms have been suggested including that a direct link between motor development and stunting delays the age of attainment of walking [99, 100]. Indirect mechanisms include the role of infections, which are more frequent in undernourished children due to their weaker immune system. Children who are ill more frequently had lower cognitive scores in the MAL-Ed cohort [101]. Also, parents and caregivers may not provide age-appropriate stimulation to stunted children as they may appear apathetic and younger [102]. There is also a possibility that different domains of child development influence each other. For example, motor development may impact cognition as children with higher self-mobility have more opportunities to explore their environments [103].

Appropriate child development also is highly dependent on external factors such as optimal stimulation. Interventional and observational studies showed that adequate stimulation can increase child development scores [94, 104-106]. Moreover, household environment such as exposure to violence and to maternal depressive symptoms can affect negatively the development of children [94].

Impaired development in the early years can limit children in achieving their full potential later in life [9]. Measures of early child development have been associated consistently with academic performance [107, 108]. According to the latest estimates from 2010, 250 million children (43%) under the age of five living in LMICs were not on track to fulfill their

developmental potential [109]. This alarmingly high number calls for an increased investment in research and effective interventions to prevent the long-term negative effects on productivity.

Child development assessment

Children go through the stages of development sequentially according to their age, allowing researchers to establish milestones for appropriate development. These developmental milestones provide an indication that a child is developing appropriately compared to most of the children in the same age category. Multiple tests are available to assess various domains of child development. The Bayley's Scales of Infant and Toddler Development is widely used in research and practice to assess developmental functioning in children from one month to 42 months [110]. The tool was originally intended to identify patterns of developmental delays in children but it has since been modified to enable assessment of appropriate development in different age categories. It measures five domains of child development including cognition, language, motor skills, socioemotional development, and adaptive behavior. The Bayley Scales includes both direct assessment of a child's development (cognition, language, and motor skills domains) with test items as well as a questionnaire for parent or primary caregiver (socioemotional development and adaptive behavior). Briefly, the infant is asked to perform tasks with an increasing level of difficulty. Depending on how many test items the infant completes, they will be given a score evaluating their developmental stage [111].

For the cognitive abilities, the Bayley scale assesses the concepts that are known to be associated with cognition in children. Information processing (attraction to new objects, anticipation of patterns, memory, etc.) and number concepts and counting are assessed in this subtest. The child is expected to play with certain objects or to be curious about new shapes and colors, depending on their age.

The language subtest assesses both receptive and expressive language. For receptive language, the child is tested on their ability to understand and respond to the people and sounds around them. The subtest includes responding to their names, or participating in play routines or nursery rhymes. In the expressive language section, the child is evaluated on their ability to vocalize and imitate sounds or words, and saying words depending on their age. These include babbling and cooing and one-word approximations.

The motor scale includes both gross motor and fine motor subsections. The gross motor subtest assesses the child's achievement of the milestones in locomotion: sitting, crawling, standing, etc. The fine motor subtest evaluates the more controlled movements and coordination, for example the grasp of smaller objects [111].

7. Nutrition interventions

Complementary feeding interventions

Given the importance of adequate complementary foods on child growth and development, improving complementary feeding practices has been widely used as a strategy to promote child growth in LMICs. The Lancet series on Maternal and Child Undernutrition identified complementary feeding interventions as effective to reduce child undernutrition in countries with the highest burden [112]. Table II.3 summarizes results from meta-analyses performed on randomized trials in several countries. Maternal education on complementary feeding alone can improve child weight and length, especially in food secure populations, though the effects are modest. Specific messages aiming to increase dietary diversity have been identified to be effective. Longitudinal analysis from 1970 until 2010 showed that the increase in dietary diversity is one of the underlying factors that had the greatest impact in reducing child stunting in

LMICs [113]. Provision of complementary foods with or without education provides greater effect on child growth than nutrition education alone.

Table II.3. Summary of meta-analyses on the effects of nutrition education with or without food provision on child growth in low- and middle-income countries.

Intervention	Growth indicators	Black *et al.* (2017) [112]	Dewey & Adu-Afaewuah (2008) [114]	Imdad *et al.* (2011) [115]	Panjwani *et al.* (2017) [116]	Arkipo *et al.* (2018) [117]
Age group		6-59 months	6-24 months	6-24 months	6-24 months	4-24 months
Nutrition education alone	Weight	-	-	0.30 (0.05-0.54)	-	0.06 (-0.04-0.15), weight at 12 months
	Length	0.25 (0.01-0.49)	-	0.21 (0.01-0.41)	0.22 (0.08-0.37) for food secure; -0.05 (-0.24-0.15) for food insecure	0.32 (0.11-0.52), length at 12 months
	Weight-for-length	-	-	-	0.21 (-0.06-0.48)	
Complementary food provision (with or without education)	Weight	-	0.60 (-0.22-2.99), without education	0.34 (0.11-0.56)	-	-
	Length	0.41 (0.05-0.76)	0.47 (-0.04-1.81), without education	0.26 (0.08-0.43)	0.10 (0.03-0.17)	-
Quality of evidence		Not stated	Moderate to high	Moderate	Moderate to high	Low to very low

Results expressed as weighted mean difference WMD (95% confidence interval).

Agriculture-based interventions

Interventions addressing underlying factors of child undernutrition have been tested and implemented under the category of nutrition-sensitive programs. Agriculture-based interventions

such as home gardening, biofortification, and small animal farming have great potential to improve nutrition outcomes in children [118]. Impact evaluations of these programs reported positive results on child dietary diversity and consumption of animal-source foods [119-121]. The effects on child undernutrition are inconclusive and there is no strong evidence to date to support that agricultural interventions can reduce child undernutrition. However, these mixed results may be due to weaknesses in program evaluation design and inadequate statistical power [118, 121]. Also, other important factors influencing children's nutritional status have not been always considered such as hygiene and sanitation and the intervention periods may be too short to see positive effects. However, some of these factors are highly dependent on available resources such as funding.

Multiple pathways have been suggested to explain the potential links between agriculture and child nutrition including improvement in food access and availability of nutritious foods and as a potential source of income for the household [118]. Other possible pathways include a change in women's status and her control over productive assets as well as her time for household and child care, which can have positive or negative impacts on child nutrition. Agriculture-based interventions may not reduce child undernutrition directly but they provide a sustainable opportunity to improve access to and availability of higher quality diets in vulnerable households.

WASH interventions

A meta-analysis of RCTs investigating the effects of WASH improvements in reducing child undernutrition was conducted in 2013 and reported a small but significant increase in LAZ [WMD 0.08 (0.00-0.16)] [122]. After that finding, several trials were implemented in different countries under the WASH Benefits and the Sanitation Hygiene Infant Nutrition Efficacy (SHINE) projects [123, 124]. These studies tested the effects of individual, full WASH or combined WASH and nutrition on child growth and development. The results are summarized in

table II.4. Improved WASH only did not always improve child growth, in contrast with improved nutrition. However, combined WASH and better nutrition consistently improved child length and weight in all studies. These results reinforce the multifactorial aspects of child malnutrition and suggest that integrated approaches are more effective to promote child growth during the first two years.

Table II.4. Summary of WASH intervention trials on child growth in low- and middle-income countries.

Growth indicators	Intervention groups	Mali [125]	Bangladesh [126]	Kenya [127]	India [128]	Zimbabwe [129]
	Study length	2 years	2 years	2 years	30 months	Minimum 18 months
LAZ	WASH only	0.24 (0.09-0.40)	0.02 (-0.09-0.19)	-0.03 (-0.14-0.08)	-0.10 (-0.22-0.02)	-
	Nutrition only	-	0.25 (0.15-0.36)	0.13 (0.01-0.25)	-	0.14 (0.07-0.21)
	WASH and nutrition	-	0.13 (0.02-0.24)	0.19 (0.08-0.31)	-	0.06 (-0.01-0.12) Compared to nutrition only
WAZ	WASH only	0.16 (0.01-0.31)	0.00 (-0.09-0.10)	-0.02 (-0.12-0.08)	-0.01 (–0.12-0.09)	-
	Nutrition only	-	0.24 (0.12-0.35)	0.11 (0.00-0.21)	-	0.13 (0.07 to 0.19)
	WASH and nutrition	-	0.13 (0.04-0.22)	0.14 (0.04-0.25)	-	0.00 (-0.06-0.06) Compared to nutrition only
WLZ	WASH only	-	0.00 (-0.10-0.11)	-0.02 (-0.10-0.07)	-	-
	Nutrition only	-	0.15 (0.04-0.26)	0.04 (-0.05-0.14)	-	-
	WASH and nutrition	-	0.09 (0.00-0.18)	0.09 (0.00-0.19)	-	-

Results are expressed as mean difference MD (95% confidence interval) between the control group and the intervention group

LAZ: Length-for-age z-scores; WAZ: Weight-for-age z-scores; WHZ: Weight-for-height z-scores

Integrated nutrition interventions with child stimulation

The evidence of the timing of rapid growth and high neuroplasticity during the first two years strongly suggests that integrating early child development with nutrition interventions may be most effective in preventing both undernutrition and poor development [109, 130-132]. Several trials as well as government programs were implemented in LMICs [133] but a recent systematic review reported that there is not enough evidence supporting positive synergistic effects of nutrition and stimulation on child development [106]. Child stimulation consistently improved child development but when tested together with better nutrition, did not show significant effect. However, this conclusion was drawn from only four studies that tested the combined or separate effects of nutrition or stimulation on child growth and/or development. Also, differences in study design and components, study duration (from 6 months to two years), and baseline nutritional status of the infants may contribute to the mixed results reported. One of the main reasons for promoting integrated interventions was the conclusion that the health and nutrition structures already in place in most countries provide the best entry point to incorporate child stimulation [109]. Child nutrition and stimulation are critical but the most recent Lancet series suggested a broader and more comprehensive framework called Nurturing Care to promote optimal child development during the first two years and beyond [132]. In addition to health and nutrition, aspects of child protection and safety are incorporated. The child's environment has to be safe, provide adequate stimulation, and adults need to be responsive to the child's biological and emotional needs. Multi-sectorial packages targeting the household as a whole rather than the child or the mother only are then likely to be successful.

Use of behavior change theories in nutrition interventions

Nutrition interventions tend to be more successful when targeting specific behaviors using theories of change [134, 135]. Behavior change interventions have been successful in

promoting appropriate feeding practices in LMICs [88, 136-138]. Behavior change theories can inform the design and the evaluation of interventions by identifying necessary information to increase the effectiveness and impact of the program [134]. Theories can also help in understanding behaviors and their determinants. Depending on the context, the goal, and the needs assessment, multiple behavior change theories can be applied; but the transtheoretical model, the social cognitive theory, and the social ecological model are commonly used. In the transtheoretical model, behavior change is a process occurring through five stages of change [139]. The first stage, called "precontemplation", individuals do not intend to change their behaviors and they have little to no awareness of the risks of their current behaviors. In the "contemplation" stage, individuals are aware of the consequences of their behaviors as well as the benefits of changing, but there are barriers preventing the change. Individuals in the "preparation" stage are ready to make the changes and have plans on how to achieve them. In the "action" stage, individuals are taking actions and adopt new habits. And in the final stage, called "maintenance", the desired behavior is established. The progress through the stages of changes is not necessarily linear and it is possible that individuals may relapse and fall back to previous stages over time.

The social cognitive theory (SCT) suggests that there is constant interaction between behaviors, the individual, and the environment [140]. This key element of the SCT is called "reciprocal determinism" and a change in one or two of these factors is likely to result in a change in the third factor. The main constructs in the SCT include outcomes expectations, self-efficacy, external facilitators and impediments [141]. Outcomes expectations are the perceived risks and benefits of the desired behavior, which can be physical, social or self-evaluative. Self-efficacy includes both the self-confidence and the ability to make the behavior change. External facilitators and impediments are barriers and enablers that prevent or facilitate the change in behavior. Another important construct of the SCT is observational learning, indicating that

individuals learn and adopt behaviors from their own experience but also from observing others. In addition, external reinforcement from other members of the community can also facilitate or impede the shift to the desired behavior.

The social ecological model (SEM) indicates the multiple levels of influence of external factors on the behaviors of interest [134, 141]. The SEM is particularly helpful in identifying influencing factors that can be present at the personal, interpersonal, organizational, and community levels. Changing the environment by addressing factors at multiple levels will facilitate the behavior change.

8. Fathers' involvement in child care

Even though childcare is generally perceived as the mother's responsibility, the father plays a central role in decision making in most of the households in LMICs. A few studies have demonstrated that fathers' involvement in child care has positive outcomes in both feeding practices and child growth. In a 6-month longitudinal study in Kenya, fathers and grandmothers were engaged in bimonthly dialogues based on the WHO and Kenyan government recommendations for complementary feedings [13]. Mothers were six times more likely [OR=6.1, $p<0.01$] to give their infant animal-source foods if their husband was in the intervention group. Also, mothers who received social support from the husband and the grandmothers were significantly more likely to feed their children the minimum number of meals a day compared to the control group [OR=1.14 (1.00-1.30), $p<0.05$]. Findings from a comparative study in northern Ethiopia showed that fathers' knowledge of important food groups in complementary foods and general child health was associated with higher odds of meeting the MDD in both rural and urban districts [142]. Similarly, infants whose fathers were involved in feeding and in routine child care activities were more likely to meet the MDD. Another study from Ethiopia also reported similar

results where fathers' involvement was associated with increased odds of meeting MDD [143]. In addition, a recent study conducted with Ethiopian coffee farmers also confirmed that fathers' involvement in childcare and nutrition was associated with an increase of 0.42 HAZ in children under the age of two [144].

Including fathers in interventions aiming to improve child growth and development may then provide additional benefits and is in line with the Nurturing Care framework. However, in conservative societies such as the sub-Saharan African context, there are often strong expectations for gender roles in child care [12, 14]. A few qualitative studies have investigated the perceptions of fathers of their roles in child care and what are the barriers and enablers to their engagement in routine child care activities. Fathers usually consider child care as the primary responsibility of the mother and perceive themselves as providers [12, 145, 146]. They engage in some activities such as feeding or playing with the child but only under certain circumstances, mainly when the mother is not available. Bilal and colleagues [147] argue that the perceptions of Ethiopian fathers on their responsibility regarding child feeding have changed over the years, and they are now more open to receive information on child care practices. Similar results were reported from Rwanda where men want to be more engaged in child care and nutrition [14].

Several barriers to fathers' involvement in child care have been identified. First, there is a low perceived social support for involvement and strong cultural gender norms on child care [14, 145]. Another potential barrier is that fathers' knowledge regarding nutrition and child development is limited compared to mothers and other female caretakers [12, 145]. Fathers in Ethiopia also perceived that services related to child care at the local community centers did not encourage their participation and were geared more towards the mothers and other women [147].

With the accumulating evidence of the potential effects of fathers' engagement on feeding practices and growth, there are currently a few intervention studies being conducted in

LMICs on the topic. A clustered randomized trial in Ethiopia tested the effects of separate and combined weekly nutrition education sessions for mothers and fathers using behavior change communication [148]. Preliminary results showed an increase in child dietary diversity score in the combined mothers and fathers group compared to the control. Another similar trial is also being implemented in Tanzania where mothers and fathers are randomly assigned, separately or together, in the nutrition groups or nutrition and child development groups.

The Bayley Scales have been used widely in studies evaluating at the effect of fathers' engagement and parenting styles on child development. However, most of the studies have been conducted in high-income countries. Two-year-old children with supportive and enthusiastic fathers had higher language, cognitive and emotional regulation scores in the Early Head Start Research and Evaluation project [149]. The same study reported infants whose fathers had higher modernity scores and who were more focused on their children and more encouraging were more likely to have higher cognitive scores [150]. A longitudinal study conducted in the UK showed that 3-month old infants whose fathers were more engaged, more sensitive and less controlling had higher cognitive scores measured with the Bayley Scales at 24 months [151]. The effect was independent of maternal sensitivity.

Parenting studies and interventions are more frequent in high-income countries than in LMICs. However, there are a few such studies that are being carried out. For example, a cohort study on maternal perinatal depression, fathers' involvement, and child development was conducted in Pakistan. Child development was assessed using both the Ages and Stages Questionnaire and the Bayley Scales at 12 months. Results showed that higher level of fathers' involvement significantly predicted higher fine motor skills in children [152]. And there was a trend of overall positive effect of fathers' involvement across the child development domains, although results did not reach statistical significance. In summary, there are limited studies

examining fathers' involvement and child development that were conducted in LMICs. And there is still the concern of validity and the relevance of the Bayley Scales in the local context.

9. The case of Madagascar

Despite the fact that Madagascar has one of the highest burdens of child undernutrition, the topic is still understudied. The latest Multiple Indicator Cluster Surveys (MICS) data reported that only 25% of infants under the age of two received the MDD and only 21% met the MAD in 2018. Many more infants were given complementary foods the recommended number of times (79%). In the Vakinankaratra region, only 31% of infants achieved the MDD despite the high agricultural production. Complementary foods consisted mostly of starchy items, mainly rice, and consumption of animal source foods such as meats and eggs was very low [153-155]. A few studies analyzed the determinants of optimal complementary feeding practices. Maternal factors such as more education and age at first birth of more than 19 years have been associated with higher odds of meeting the MDD. Household related factors such as higher wealth index and living in urban areas were also associated with higher likelihood of achieving MDD [155, 156].

Qualitative studies in various rural communities of northern and eastern Madagascar reported that limited access and availability are some of the main barriers to more diverse diets [154, 157]. Two studies analyzed the caregivers' beliefs regarding nutritious foods and their criteria for purchasing and cooking them for their children in the eastern [154], central and northern [153] regions of the country. Cereals, usually rice, were more often cited as nutritious foods compared to any other food groups in both studies. Other foods considered nutritious were seafood, meat, and fruits. Interestingly, green leafy vegetables were not considered nutritious in either study populations.

A secondary analysis of the 2009 DHS found that determinants of child stunting were different for different age groups in Madagascar [7]. Increased child age, being male, anemic, and living in a rural area were associated consistently with higher odds of being stunted in both the 0-23 and the 24-59 mo age groups. An analysis of the baseline data of a cohort study reported that parasite infection (*Trichuris trichura*), lower household wealth, low birthweight, tight birth spacing, and more frequent respiratory infection symptoms were associated with increased likelihood of being stunted [158]. When measured, shorter maternal height was also consistently associated with increased odds of stunting [7, 159].

Although several nutrition interventions have been implemented in different parts of the country, only a few of the evaluations were published. The evaluation of the national community nutrition program called *Surveillance et Education des Ecoles et des Communautés en matière d'Alimentation et de Nutrition Elargie* (SEECALINE), completed in 2011, was recently published [160]. The SEECALINE program targeted children under five years and pregnant and lactating mothers to improve their nutritional status. Interventions including monthly growth monitoring, cooking demonstrations, group nutrition education sessions, and vitamin A supplementation were implemented by local Non-Governmental Organizations (NGO) through the community centers and the *Agents Communautaires de la Nutrition* (CNA) [161]. The first phase (1999-2004) targeted only districts with high underweight rates but the second phase (2005-2011) had national coverage. The recent evaluation analysis included data from baseline (1997) and from two rounds of surveys in 2004 and 2011. The original communities who were exposed to the first phase of the program had higher child HAZ and WAZ compared to those who were not targeted [160]. The positive effects on length and weight were sustained until 2011. However, there was no significant effect of the program on the communities who were included during the second phase. The low impact of SEECALINE was attributed to differences in educational levels and trainings of the CNAs between the two phases and an increased workload

for the CNA's for the second phase. The national program was just recently revamped and new community centers will be added to increase the coverage. Also, in addition to the usual SEECALINE intervention package, the CNAs will be working closely with the community health workers to improve maternal and newborn health.

The WHO's Essential Nutrition Actions (ENA) framework was also implemented and tested in the highland regions of Madagascar in the early 2000's. The ENA targets lactating women and children under two with a focus on reducing morbidity and mortality. Exclusive breastfeeding during the first six months, appropriate feeding of the sick child, reduction of anemia, and prevention of vitamin A and iodine deficiencies are emphasized in this framework. Results showed that early initiation of breastfeeding increased by 35%, exclusive breastfeeding increased by 32%, and the proportion of children fed the minimum number of times increased by 8% during the five years of implementation [162].

A large integrated nutrition and child development intervention was implemented in five regions in the southeastern part of the country [163]. This cluster-randomized controlled trial enrolled pregnant women and children under two who were followed for two years. The study tested the effectiveness of home visits combined with provision of lipid-based nutrient supplements (LNS) on child growth and development. The intervention showed no overall effect either on child anthropometrics nor on child development scores at endline [164]. Long distances between communities, low responsivity of the mothers, and little supervision of the community health workers who conducted the home visits have been suggested as reasons for the low impact of the interventions. Mothers reportedly were not engaging with the community health workers or were not able to act on the suggested behavior change, perhaps due to poverty and food insecurity. Besides the national community nutrition program, there has not been a study implemented in the Vakinankaratra region despite its very high stunting rates.

Summary

Child undernutrition remains a public health issue in LMICs, including Madagascar. Primarily caused by inadequate nutrition, growth is influenced by multiple factors at the child, household, and community levels. Undernourished children are at higher risks of infectious diseases and mortality. Undernutrition during infancy and early childhood also leads to poor academic performance and ultimately will reduce productivity in adulthood. The first two years of life offer a unique opportunity to prevent the short and long-term negative consequences of child undernutrition because of the rapid growth. Concurrently, brain plasticity is also at its highest during that period with high nutrient demands. Thus, adequate nutrient intakes as well as appropriate stimulating environments are crucial to promote growth and development of children and to provide opportunity to fulfill their full potential.

In addition to nutrition-specific interventions such as food provision and nutrition education to improve feeding practices, programs integrating WASH or agriculture and nutrition may be beneficial. Also, engaging fathers in child care activities has shown positive results on child nutrition and development outcomes.

Madagascar is among the countries with the highest burden of malnutrition. Despite being agriculturally productive and the coverage of the national community nutrition program, child undernutrition rates in the Vakinankaratra region are very high. Yet, there are limited data on the individual and underlying factors that influence child growth and development in the region.

CHAPTER III

METHODS

This study used a mixed-methods approach. Data were collected using focus group discussions, individual in-depth interviews, and a cross-sectional survey with observational components.

1. Study population and research setting

This study was conducted in the Vakinakaratra region of Madagascar, which is approximately 170 km south of the capital city Antananarivo. It is one of the most agriculturally productive regions of the country and has been the largest rice and corn producer since 2013. Most of the legumes and vegetables, including various types of beans, carrots, and green beans, also grow well in the region. The dairy industry is also concentrated in Vakinankaratra. It is the second most populated region of Madagascar with a total population of 2,074,358. There is one urban district, Antsirabe I, and six rural districts: Ambatolampy, Antanifotsy, Antsirabe II, Betafo, Faratsiho, and Mandoto. The districts Betafo and Mandoto were not included in the randomization list because of safety issues and the difficult access. Faratsiho also was excluded because of the lack of access during the rainy season, and Antsirabe I was not included because of its urban population.

The districts Antanifotsy and Antsirabe II were randomly chosen from the remaining rural districts for the study location.

Due to the well-established importance of nutrition on child growth and development during the first 1,000 days, this study focused on children under the age of two and their households. Mothers were eligible to participate in the study if they had a child between 6 – 23 months, if they lived with their husband or partner, and if they or their child did not have chronic illness.

2. Qualitative methods

Focus group discussions and in-depth interviews of local key informants were used to collect qualitative data (table III.1). Data collection took place in April 2019.

Focus group discussions (FGD)

A total of 10 focus group discussions were conducted among mothers and fathers. Participants were recruited from seven fokontanys (smallest administrative unit) from the Antanifotsy (3) and Antsirabe II (4) districts. To avoid possible conflicts and bias during discussion, fathers and mothers had to come from different households. The included fokontany were chosen because the Community Nutrition Agents (CNAs) were available at the time. The CNAs helped in recruiting participants who would be willing to participate in group discussions regarding feeding practices and fathers' involvement in child care. Eligible participants were approached and were given information about the project and were asked to sign the written consent forms if they wanted to participate. The focus group discussions were conducted in Malagasy at the community nutrition sites and were audio recorded. Each focus group included

six to eight participants and the average discussions length was 40 minutes for mothers and 25 minutes for fathers. The researcher asked probing questions and encouraged participants to discuss further. Data saturation was achieved when no new information was shared during each focus group and each interview.

Table III.1. Qualitative data collection tools, subjects and participants

Data collection tools	Subjects	Topics discussed	Participants
Focus group discussions (7)	Mothers of children aged 6-23 months	Child feeding, hygiene, child home stimulation, fathers' involvement in child care activities	46
Focus group discussions (3) and interview (1)	Fathers of children aged 6-23 months	Child feeding, child home stimulation, fathers' involvement in child care activities	17
Individual in-depth interviews	Community Nutrition Agents (CNAs) (6), nurse (1), NGO worker (field program monitor) (1)	Child feeding, hygiene, child home stimulation, fathers' involvement in child care activities	8

Individual in-depth interviews (IDI)

Semi-structured interviews were conducted among key informants in the community including CNAs (6), a nurse practitioner, and a field program monitor. The key informants were chosen based on their experience and their relationship with the community. The CNAs and the field program monitor all had been in their positions for at least 5 years; thus, they were able to provide valuable information regarding the community. The nurse was added as per recommendation of the ethics committee of the Malagasy Ministry of Public Health to provide the perspective of the medical staff. Another interview was conducted with a father of a child younger than two because there were not enough participants for a focus group discussion. The IDI provided additional perspective to the data and were conducted as means of triangulation of

the information obtained from the mothers and the fathers. Interviews were conducted in Malagasy and audio recorded. The average length of the IDI was 26 minutes. Similar to the FGD, the researcher asked probing questions and saturation was achieved when no new information was given during the interviews.

Focus group questions and interview guide

Questions were framed based on previous relevant research and the specific questions the researchers wanted to explore. Questions for the FGD are summarized in table III.2 and III.3, and the interview guide for the key informants are in table III.4. The questions were reviewed by the doctoral committee members and then translated in Malagasy. The translated version was further reviewed by other native speakers, two mothers and two fathers of children younger than five years, before the discussions. After final revisions, no formal adjustments were done on the questions as data collection progressed. However, the researcher changed the way the questions were framed and asked according to the local context.

Table III.2. Questions for the focus group discussions (mothers)

Complementary feeding
1. What kinds of complementary foods do you give your child?
2. How important is it to you that your child has adequate complementary foods?
3. How do you decide when to give the child complementary foods?
4. How do you decide what to give the child for complementary foods?
5. If you have questions about complementary foods, who do you ask?
6. If you want to change the foods you give your children, what would make it difficult to do so?
WASH practices
1. How important is it for you to raise your child in a clean environment?
2. If you have questions about sanitation and hygiene and child feeding, who do you ask?
3. If you wanted to have better hygiene practices, what would make it difficult to do that?
Child stimulation practices
1. What do you do when you spend time with your child?
2. How important is it to you to find time to play/talk to your child?
3. If you wanted to play and talk to your child more, what prevents you from doing so?

Fathers' involvement in child care
1. What kind of activities does your husband/partner do with the child?
2. What prevents him from being more involved in activities with the child?
3. How would you feel about getting him more involved in activities with the child?
4. How would you go about getting him more involved in activities with the child?
5. What would the neighbors/other community members think/say if he is more involved?

Table III.3. Questions for the focus group discussions (fathers)

Complementary feeding practices
1. What kinds of complementary foods do you give your child?
2. In the household, who decides what food to give to the child? Why?
3. How would you feel about getting more involved in complementary feeding?
4. If you wanted to be more involved in feeding the child, what would make it difficult to do so?
Child home stimulation
1. How important is it for you to find time to play/talk to your child?
2. If you wanted to play and talk to your child more, what prevents you from doing so?
Fathers' involvement
1. What are the responsibilities of fathers regarding childcare?
2. What kind of activities do you do with your child?
3. How do you support your wife/partner in raising your children?
4. What activities would you like to do more with your child?
5. If you wanted to be more involved in childcare, what prevents you from doing so?
6. What would the other fathers think if they saw a father being involved in child care activities more than usual?

Table III.4. Interview guide for the key informants

Complementary feeding practices
1. In the household, who decides what food to give to the child?
2. If parents have questions about complementary foods, who do they ask?
3. If parents wanted to feed their child better, what would make it difficult to do that?
4. If parents wanted to have better hygiene practices, what would make it difficult to do that?
Child stimulation
1. How important is it for mothers to find time to play/talk to their child?
2. How important is it for fathers to find time to play/talk to their child?
Fathers' involvement in childcare activities
1. What do people think are the responsibilities of the fathers regarding child care?
2. What prevents fathers from being more involved in activities with the child?
3. What would the neighbors/community members say if they see fathers getting more involved in activities with the child?

Data preparation and analysis

Saturation was reached when no new responses were given during the focus group discussions and the interviews. The FGD and the IDI were transcribed verbatim by a native Malagasy speaker and back-translated into English by the researcher before analysis. A thematic analysis approach was used to analyze data [165, 166]. Two group of researchers coded the data using NVivo v. 12 (QSR International, Melbourne, Australia). Codes were created from patterns in the data (inductive approach) and from the interview questions (deductive approach). Discrepancies were discussed and resolved when researchers disagreed during coding, however, there was less than 5% initial disagreement. Codes with similar characteristics were grouped into themes in order to answer the research questions. Development of themes was also done with the assistance of two other researchers. Field notes taken by the researcher were used throughout the data analysis and the writing process to add context to the data.

Trustworthiness and reliability

To increase the trustworthiness of the results, a data triangulation method was used [167]. Information was gathered from different sources (the mothers, fathers, and key informants) using various data collection tools (focus group discussions and in-depth interviews). Additionally, data were collected from participants from different communities in the rural areas of the Vakinankaratra region. Having multiple perspectives of participants living in different areas may increase the reliability of the data and may also help achieve saturation. Trustworthiness and reliability were further reinforced by the involvement of two other researchers during the development of codes and themes.

3. Quantitative methods

Sampling strategy and recruitment

A multi-stage cluster sampling was used. Based on a regional stunting rate of 55% [7] and a margin error of 0.05, 380 participants were needed [168]. Because data were collected in steps, a total of 391 mother-child dyads were enrolled in the study in case of missing data and/or loss to follow up. An initial visit with the Regional Nutrition Office in Vakinakaratra allowed for a mapping of all the areas where the government's community nutrition program (*Programme National de Nurition Communautaire* or PNNC) was implemented. To facilitate data collection and participation recruitment, only communities covered by the PNNC were included in the randomization process.

From the two districts Antanifotsy and Antsirabe II, nine communes were randomly selected. Antsirabe II had a much higher number of communes covered by the national nutrition program (20) than Antanifotsy (12), thus six communes were selected from Antsirabe II. Also, Antsirabe II had a larger population (390,070) than Antanifotsy (295,604). Communes that had difficult access (poor road conditions and inaccessible with car due to rain) were eliminated and the next commune in the potential randomization list was chosen. In the Antanifotsy district, 8 communes were eliminated out of the 12 communes covered with the national community nutrition program.

Within the selected communes, the plan was to randomly select five fokontanys from each commune. The fokontanys that take more than two hours walk to reach were excluded and the next fokontany in the potential randomization list was included. Twelve fokontanys in the original potential randomization list were replaced: two fokontanys in the Antanifotsy district and 10 fokontanys in the Antsirabe II district. Then, in the Antanifotsy commune, 10 fokontanys were chosen because of its higher number of fokontany with the community nutrition sites (22) compared to Ambohimandroso (6) and Ampitatafika (6).

Within each fokontany, an average of 8 eligible mothers was selected from the most recent census conducted by the CNAs. Details of the number of participants in each fokontany are summarized in appendix 2. Potential participants were approached and given information about the study. They were asked to sign the consent forms before any data were collected. Data collectors were trained for three days on ethics in conducting research with human subjects and in interpersonal communication in addition to the content of the questionnaire.

Anthropometric measurements

During the measurements, children only wore light pieces of clothing. Child recumbent length was measured to the nearest 0.1 cm using a locally made wooden length board. The CNAs or one research assistant helped to ensure the child was laying still. Length was measured twice and the average was taken. Child weight was measured using hanging scales (type SECA).

Mothers' height was measured with a non-stretchable tape to the nearest 0.1 cm. Mothers were asked to stand against a wall with heels and buttocks touching the wall. They also wore light clothes, and headscarves and shoes were removed before measurement. When scales were available, maternal weight was also taken.

Survey questionnaire

Factors that have been shown to influence child growth and development in related studies were assessed. The questionnaire included 9 sections (appendix 3).

Sociodemographic information

The sociodemographic section included questions related to the mother and the household such as age, education, head of household, and agricultural land ownership based on

the Demographic and Health Survey [169]. Drinking water source, sanitation, and the child's morbidity were also asked. Information regarding maternal media exposure as well as household physical assets were collected.

Food insecurity

The Household Food Insecurity Access Scale (HFIAS) [170] questionnaire was used. It includes 9 Yes/No questions pertaining to uncertainty regarding food supply, insufficient food quantity and quality, and its consequences for the household members. It also includes 9 follow-up frequency questions when the respondent answers "yes". Results can be transformed into individual scores with high scores indicating more severe food insecurity. A question about how long the last rice production lasted was also added to this section.

Maternal feeding knowledge

This section started with the source of nutrition information of the respondents. A set of 15 questions were developed based on the WHO's Guiding Principles for Complementary Feeding of the Breastfed Child [59]. Questions regarding the length of exclusive breastfeeding, the appropriate age of introduction of complementary foods, and the appropriate feeding were asked. Maternal knowledge of responsive feeding was also assessed. The questions had multiple options but mothers were encouraged to answer first without being given the choices to reduce bias. Responses were coded "0" when incorrect and "1" when correct. A total knowledge score was calculated for each mother based on the expected answers.

Complementary feeding practices

The WHO Infant and Young Child Feeding indicators (IYCF) were used [171]. Because only children aged 6 – 23 months were enrolled, only the complementary feeding indicators were assessed. These include minimum dietary diversity, minimum meal frequency, minimum acceptable diet, and consumption of iron-rich foods. The indicators are based on a recall of the

feeding practices the previous day. Complementary foods were then classified in 7 food groups during data cleaning: grains, roots and tubers; legumes and nuts; dairy products; eggs; flesh foods (meat, fish, poultry, organ meat); vitamin A-rich fruits and vegetables; and other fruits and vegetables. No quantity restriction was made and all ingredients, except condiments, were accounted for in the case of mixed dishes [171]. For the meal frequency, following the recommendation, snacks and meals were both counted because both contribute to energy intake. No iron fortification programs are in place in Madagascar, so the last IYCF indicator assessed the consumption of flesh foods.

WASH knowledge

Questions concerning mothers' knowledge regarding safe drinking water source and treatment were included in this section. Appropriate handwashing practices as well as safe child feces disposal were also asked.

WASH conditions

When possible, surveys were conducted in the participants' home; otherwise, mothers were interviewed in a private and quiet place. The spot check observational method was used for assessing hygiene practices [172]. The data collector discretely looked at the house of the respondent and its surroundings and details were noted in the checklist.

Child home stimulation knowledge

A total of six questions were asked regarding the importance of parents talking and playing with their children. A 3-item Likert scale: "not important", "somehow important", "very important" was used.

Child home stimulation

Questions in this section were guided by the Family Care Indicators (FCI) [173]. These indicators mainly assess the available support for child stimulation in a household. Types of toys

available as well as the types and frequency of activities done with the child over the last week were asked.

Fathers' involvement in child care

The 9 questions in this section were based on the study conducted by Abate and Belachew [144] in Ethiopia. The mothers were asked the frequency at which their husbands were engaged or participated in activities related to child care using a 3-item Likert scale: "not at all", "sometimes", and "all the time".

The questionnaire was translated into Malagasy and was reviewed by three other native speakers. Then, the questionnaire was pre-tested on 10 mothers with children younger than 2 years who were not included in the study. No formal adjustments were made to the questionnaire but the pre-test gave the data collectors insights regarding probing questions and how to administer the survey smoothly.

Child development assessment

The development of a subsample of children aged 11 – 13 months was assessed using the third edition of the Bayley Scales of Infant and Toddler Development (Bayley-III) [111]. A total of 38 children were completed all the five subdomain assessments (gross motor, fine motor, receptive language, expressive language, and cognition). The Bayley-III uses a battery of tests on the child to assess cognition, language skills, and motor development. Children received scores of "1" if they successfully showed the desired behavior and "0" otherwise. Assessment typically starts at different stages for different age groups because it is assumed that children would have successfully completed the previous tests. We started the tests for the preceding age group, < 11 months, to ensure children passed. They had to have three consecutive successes to continue. Testing stopped when children received scores of 0 for five consecutive items. The tests were

conducted at the local community nutrition sites. Only the examiner, the mother and a research assistant were present in the room with the child.

To allow for children to be comfortable with the setting, the examiner and the research assistant engaged in casual discussion with the mother for few minutes. A few pictures in the picture book were changed to more culturally appropriate versions. For example, parents vacuuming was replaced by a mother sweeping the floor; also pictures of Caucasian and Asian children were replaced with pictures of Malagasy children. The tools were pre-tested on two children aged 12 and 15 months before data collection.

Socioemotional development was assessed using a questionnaire added to the household survey. Questions were translated in Malagasy, then reviewed by two mothers and two fathers of children younger than 2 years who were also native speakers. Probing questions were used by the interviewers as necessary to help the mothers better understand the concepts being asked.

Raw scores for each subtest of child development assessed were obtained by counting the total of success items until ceiling was reached and adding the items for the previous age group, because it is assumed the child would have successfully passed them [111]. Raw scores were then converted to scaled scores to allow for similar age group comparisons. Scaled scores range from 1 to 19 with a mean of 10 and a standard deviation of 3. Composite scores were also calculated for each domain: cognitive, motor development, language skills, and socioemotional development, on a scale of 40 to 160 with a mean 100 and a standard deviation of 15. The composite scores can also be used to compare the performances of children of the same age. And percentile ranks were obtained to compare the development of the tested child to the Bayley's standardization sample (1,700 children aged 1 month to 42 months from across the USA).

4. Statistical analyses

For descriptive statistics, means and frequency distribution of variables were used. Length and weight were converted into length-for-age z-scores (LAZ), weight-for-age z-scores (WAZ), and weight-for-length z-scores (WLZ) using WHO Anthro v. 3.2.2 before analysis. Continuous dependent variables (LAZ, WAZ, and WLZ) were checked for normality using their histogram distributions. Only LAZ was not normally distributed and was transformed using the logarithm function after adding a constant value of eight. A tertile wealth index was constructed based on household assets [174].

For study 1, a series of logistic regressions were performed to assess the association between the outcomes of interest and the independent variables. Odds of stunting, underweight, and wasting were calculated. Stunting (LAZ < -2), underweight (WAZ < -2), and wasting (WLZ < -2) were based on the 2006 WHO Growth standards [16].

Known covariates from previous studies were included in the model to adjust for confounding factors. Also, the models were adjusted for the clustering during survey design. Table III.5 summarizes the variables used and the regression models conducted in study 1.

Table III.5. Study objectives, variables used, and covariates for study 1

Objectives	Outcomes	Independent variables	Covariates	Odds ratio calculated
Association between maternal knowledge of child feeding and complementary feeding practices and	Minimum dietary diversity	Maternal knowledge of child feeding (total score)	Maternal age at first birth, head of household, exposure to radio, number of living children, food insecurity access score	Odds of meeting the minimum dietary diversity
	Minimum meal frequency			Odds of meeting the minimum meal frequency
	Minimum acceptable diet			Odds of meeting the minimum acceptable diet
	Consumption of iron-rich foods			Odds of consumption of iron-rich foods

Association between child growth and complementary feeding practices	Child nutritional status (stunting, underweight, wasting)	Minimum dietary diversity, minimum meal frequency, minimum acceptable diet, consumption of iron-rich foods	Child age, child sex, birthweight. LAZ models additionally were adjusted for maternal height	Odds of being stunted, underweight, and wasted
Association between child growth and maternal knowledge of child feeding	Child nutritional status (stunting, underweight, wasting)	Maternal knowledge of child feeding (total score)	Child age, maternal height, child sex, birthweight for LAZ Child age, child sex, birthweight for WAZ and WLZ	Odds of being stunted, underweight, and wasted

LAZ: Length-for-age z-scores; WAZ: Weight-for-age z-scores; WHZ: Weight-for-height z-scores

For study 3, linear regression models were used to identify the predictors of child growth using LAZ, WAZ, and WLZ. A framework of the causes of child undernutrition based on previous studies was used to select the sociodemographic variables tested in the models. Variables were grouped into three domains: immediate (child), underlying (maternal and household), and basic factors (appendix 4). A set of variables was tested for each domain and the adjusted R^2 and the Alaike Information Criterion (AIC) criteria were used to retain the variables that explain most of the variance of the outcome variable. A wealth index variable was created from household assets variables using principal components analysis. The model with the highest adjusted R^2 and the lowest AIC was retained. To build the final model, variables selected in the immediate, underlying, and basic factors were combined. The same model building approach was used to select the predictors in the final model. Ordinal and nominal categorical variables were

dummy coded before analysis. Multicollinearity was checked using the Variance Inflation Factor (VIF) and all values were within acceptable ranges (< 4).

For study 4, Student's t-tests were performed to assess any significant difference in scores of undernourished and children with optimal growth. The same statistical test was used to compare the scores between children who achieved the MDD and those who did not. All analyses were conducted with SAS 9.4 (SAS Institute, Cary, NC) and statistical significance was set at $p < 0.05$.

5. Ethical considerations

Approval was obtained from the Oklahoma State University Institutional Review Board (HS-18-54) and from the Malagasy Ministry of Health (010-MSANP/CERBM). All participants were informed of their rights and were given the option to withdraw from the study anytime. During the focus group discussions, participants were given instructions not to refer to anyone's name. The participants were compensated for their time with iodized salt (250 g), cooking oil (1/2 liter), and local cookies (value of 0.05 USD). Recordings from the focus group discussions are stored in a password-protected laptop only the researcher has access. The recordings will be destroyed once the manuscripts from this study have been published. During data entry, the first page of the questionnaire containing names was removed and destroyed and each mother was given a code. De-identified questionnaires were kept in a locked office only the PI and the research assistants had access to during data cleaning. Questionnaires were burned after verification of the data.

CHAPTER IV

CHILD UNDERNUTRITION AND MATERNAL KNOWLEDGE, ATTITUDES, AND PRACTICES OF COMPLEMENTARY FEEDING IN THE VAKINANKARATRA REGION OF MADAGASCAR

Abstract

The highlands of Madagascar have the highest child stunting and underweight rates in the country. Yet, there are limited data on how feeding knowledge and practices relate to child undernutrition. The purpose of this study is to assess maternal knowledge and practices of complementary feeding and association with growth of under two children in the Vakinankaratra region. Knowledge was assessed using the WHO recommendations on child feeding, and the WHO infants and young child feeding (IYCF) indicators were used to evaluate feeding practices. Child growth was measured as length-for-age (LAZ), weight-for-age (WAZ), and weight-for-length z-scores (WLZ) using the 2006 WHO Growth Standards. A cut-off of z-score < -2 was used to classify child undernutrition. Logistic regression models adjusting for survey design and known confounding variables were used to determine the association between the outcome and the independent variables. Mothers had relatively good knowledge regarding child feeding (mean = 6.4/10). The proportion of children achieving the minimum dietary diversity (35.8%) and consuming flesh foods were low (14.1%).

Higher maternal knowledge was associated with higher odds of appropriate complementary feeding practices even after adjustments. Only consumption of iron-rich foods was associated with lower odds of underweight in the adjusted models [AOR (95% CI) = 0.3 (0.1 – 0.7), $p<0.05$]. Higher dietary diversity score was associated with lower odds of stunting [AOR = 0.6 (0.3 – 0.9), $p<0.05$] only in infants 9 – 11 months. None of the IYCF indicators were associated with wasting. Focus group discussions among mothers and in-depth interviews with key informants were conducted in the local language. Transcripts were translated into English and the barriers and enablers of optimal feeding practices were identified using a thematic analysis approach. Maternal beliefs about complementary foods, mothers' workload, and very low income were perceived as barriers of optimal feeding practices. Maternal perceived benefits of giving appropriate complementary foods as well as their positive relationship with the community health workers were the main enablers of optimal child feeding. Integrated nutrition-sensitive interventions addressing these barriers while enhancing the enablers would be effective in promoting better feeding practices in the Vakinankaratra region.

1. Introduction

Feeding infants and young children with diverse, nutrient-dense, safe and developmentally appropriate complementary foods are essential in ensuring optimal growth [1-3]. Consequently, inadequate dietary intake due to suboptimal feeding practices is a common immediate cause of undernutrition. Inappropriate feeding practices have been associated with decreased growth in low- and middle-income countries (LMICs) [4-7].

The Vakinankaratra region of Madagascar has the highest child stunting (60%) and underweight (42%) rates in the country according to the latest Multiple Indicator Cluster Survey [8]. Poor feeding practices could explain, at least partially, such high child undernutrition in this region with high agricultural productivity. Only 31% of the infants and young children were fed the minimum dietary diversity in Vakinankaratra in 2018 [8]. Additionally, only 11% of those aged 6 – 23 months received the minimum acceptable diet in the central highlands of Madagascar where the region is located [9]. To support the efforts to reduce child undernutrition, improvements in complementary feeding practices are clearly needed in the region. Educational interventions targeting the mothers by increasing their knowledge have been shown to be effective to various degrees in improving feeding practices in different settings in LMICs [10].

However, data on maternal knowledge and practices of child feeding and how they relate to child undernutrition in the Vakinankaratra region are scarce. Having context-specific information about child feeding will help to understand the role of complementary feeding knowledge and practices in the child undernutrition situation in Vakinankaratra and possibly in other agriculturally productive regions with high burdens of malnutrition. Such data also could be used to inform and adjust policies and interventions aiming to improve complementary feeding practices and ultimately child undernutrition in the Madagascar highlands. Therefore, the purpose of this study was to assess the maternal knowledge, attitudes, and practices of complementary feeding and their associations with child undernutrition. The first objective is to determine

whether maternal knowledge and practices of complementary feeding contribute to the high child stunting rate in the Vakinankaratra region. The second is to identify barriers and enablers of optimal complementary feeding practices. To our knowledge, this will be the first study to use a mixed-methods approach to determine the links between child undernutrition and child feeding knowledge and practices, and to identify the barriers and enablers of optimal feeding in the Vakinankaratra region.

2. Methods

Quantitative data collection and analyses

Participants

This study was conducted in two randomly selected (out of three) districts of the Vakinankaratra region: Antanifotsy and Antsirabe II. Based on the regional stunting rate of 55% [11] and a margin of error of 0.05, we enrolled a total of 391 mother-child dyads. Participants were selected through multiple stage cluster sampling at the district, commune, and fokontany (smallest administrative unit) levels. Within the two districts, nine communes (out of 32) were selected and within each commune, 42 fokontanys (out of 84) were randomly chosen. Communes (8) and fokontanys (10) with difficult access (i.e. more than two hours walk from the main town) were eliminated and replaced by the next commune or fokontany in the potential randomization list. Within each site, we worked closely with the nutrition community agents CNAs (*agents communautaires*) to randomly select an average of eight mothers per fokontany based on their latest census. Mothers having infants aged 6 – 23 months living with her husband or a partner were eligible for the study.

Child and maternal anthropometrics

Child length was measured to the nearest 0.1 cm using a locally made wooden length board. Measurements were done in duplicate and the average length was recorded. A hanging scale (SECA) was used to measure child weight. Using the 2006 WHO growth standards [12], child length and weight were converted to length-for-age (LAZ), weight-for-age (WAZ), and weight-for-length (WLZ) z-scores. Children were classified as stunted if LAZ < -2, underweight if WAZ < -2, and wasted if WLZ < -2. Maternal height was measured against a plastic tape attached to a wall.

Survey questionnaire

A pre-tested questionnaire was used to collect sociodemographic information, maternal knowledge of child feeding, and complementary feeding practices. Questions on maternal knowledge were adapted from the guidelines for feeding of the breastfed child [13] regarding continued breastfeeding, dietary diversity, and meal frequency. A total score of correct answers was computed for each mother's knowledge and was used in the analyses. Feeding practices were assessed using the WHO infant and young child feedings (IYCF) indicators [14].

Statistical analyses

Means and frequencies were used to describe the study population. Logistic regression analyses were conducted to determine the association between selected outcome variables (complementary feeding practices and child nutritional status) and maternal knowledge of child feeding and complementary feeding practices. Models predicting the odds of appropriate complementary feeding practices were adjusted for age at first birth, head of household, mothers' frequency of listening to radio, number of living children, household food insecurity score. The models predicting child nutritional status were adjusted for child age, child sex, birthweight, and years of maternal education for WAZ and WLZ. The LAZ models were additionally adjusted for

maternal height. All models were adjusted for cluster design. Analyses were conducted using SAS 9.4 (SAS Inc., Cary, NC, USA).

Qualitative data collection and analyses

Participants

A total of seven focus group discussions with six to eight mothers per group were conducted (total n = 46). Participants had to meet the same eligibility criteria as the mothers in the surveys. Also, eight in-depth interviews were conducted with six CNAs, a nurse, and a field monitor. Focus group and interviews were conducted in the local language, Malagasy and were audio-recorded. Focus group questions and interview guides are summarized in table IV.1.

Data analysis

Recordings were transcribed verbatim and back-translated to English before analyses. Teams of two researchers coded the transcripts separately and the thematic analysis approach [15, 16] was used to identify the barriers and enablers of appropriate complementary feeding practices. NVivo v. 12 (QSR International, Melbourne, Australia) was used for analysis. Barriers and enablers were organized under three levels of the socioecological model: individual (maternal), interpersonal or household, and community.

Ethics

This study was approved by the Oklahoma State University IRB and by the Ethics Committee on Biomedical Research of the Ministry of Public Health of Madagascar. Participants gave written consent before any data collection.

3. Results

Characteristics of the study population

Most of the mothers (78.8%) were farmers (table IV.2) and had at least primary education (94.7%). The majority (71.1%) had attended at least four antenatal care sessions for their last pregnancy. Media exposure was relatively low as 56.1% had not listened to the radio the previous week. Mothers mostly received their nutrition information from the CNAs and other medical staff such as nurses and midwives. Mean child age was 14.1 months and children were almost split evenly between males and females. Stunting rates were very high (69.4%) in the study sample (table 2). A total of 23.4% of the children were underweight and 3.2% were wasted.

Maternal knowledge of child feeding

Mothers had variable knowledge of the child feeding guidelines (figure IV.1 and table IV.4). Most of the mothers had the correct answers to several of the questions except the feeding frequency for children 9 – 23 months where only 23.3% of the mothers answered correctly. Also, more than half of mothers did not think that children should eat vegetables every day. And only 63.9% knew that infants 0 – 6 months should be exclusively breastfed.

Complementary feeding practices

All indicators were low except for minimum meal frequency: 71.6% (figure IV.2). Only 35.8% of the children met the minimum dietary diversity (4 or more food groups) and only 30.2% had the minimum acceptable diet. Because of the very high breastfeeding rate (92.3%), the proportion of children meeting the minimum dietary diversity according to the new proposed scoring with eight food groups did not change much (34%) compared to the calculated 35.8%. Consumption of iron-rich foods was very low at 14.1% as was the consumption of eggs (3.3%).

Maternal knowledge and practices of complementary feeding and child nutritional status

Mothers with higher knowledge of child feeding were more likely to feed their infants from 4 or more food groups [adjusted odds ratio AOR 1.2 (95% confidence interval CI 1.1 – 1.4), p<0.05] and to reach the minimum meal frequency [AOR = 1.2 (1.0 – 1.5), p < 0.05] (table IV.5). Mothers with increased child feeding knowledge had also higher odds of giving their infants the minimum acceptable diet [AOR = 1.2 (1.1 – 1.5), p < 0.01] and iron-rich foods [AOR = 1.5 (1.2 – 1.8), p < 0.001].

Optimal complementary feeding practices were not associated with stunting or wasting after adjustments for child age and sex, birthweight, maternal age, and maternal height (table IV.6). Only consumption of iron-rich foods was associated with lower odds of being underweight [AOR = 0.3 (0.1 – 0.7, p < 0.01]. However, higher dietary diversity score was significantly associated with lower odds of stunting in infants 9 – 11 months [AOR = 0.6 (0.3 – 0.9, p < 0.05]. Additionally, maternal knowledge of complementary feeding was not associated with child stunting or wasting in the adjusted models. But higher maternal knowledge was associated with lower odds of being underweight [AOR = 0.8 (0.6 – 0.9), p < 0.05] (table IV.7).

Qualitative findings

Mothers in the focus group discussions had similar sociodemographic characteristics (table IV.8) as the participants in the survey, except for the mean age (23.3 years compared to 27.4 years in the survey). Most of the mothers were also farmers and all had at least primary education. Similar to the survey participants, nearly three fourths of the mothers had attended at least 4 antenatal care sessions but almost half (43.5%) did not listen to radio over the past week. Both barriers and enablers of optimal complementary feeding were identified at all three levels: maternal, household, and community (figure IV.3).

Maternal barriers to optimal complementary feeding

Beliefs regarding breastmilk and complementary foods were one of the maternal barriers to appropriate feeding. Many mothers started introducing foods to their infants before six months because they felt that their breastmilk was not enough or the child needed food.

> "I gave mine food after 3 months because my milk was not enough" Mother, FGD 4.

> "When the child is breastfed, he will be irritated because the milk is not enough" Mother, FGD 3.

Also, several mothers mentioned avoid giving "heavy foods" such as eggs and legumes to their young children, especially younger than one year. They stated that these foods caused vomiting and stomachache.

> "Eggs, cassava, beans…you should wait until one year to give them, but even in small quantities because their stomach can't tolerate", Mother, FGD 2.

> "Here, we don't give children eggs when they are younger than one year. Because it's difficult to digest" Mother, FGD 5.

Many mothers also perceived their workload as an obstacle limiting their time for caregiving and for complementary feeding activities specifically.

> "Sometimes, mothers are so busy they don't have time to prepare foods for their children" Mother, FGD 1.

> "We work in the field so there is no time to prepare the food for the child" Mother, FGD 4.

This was confirmed by the key informants reporting that mothers are often busy and exhausted from work and have limited time for complementary feeding. When they go for work, many mothers leave their infants with their older children.

> "Adding to that when they are tired from work already so they won't cook separately or prepare something else for the child" CNA, IDI 4.

> "The main thing is that they go to work, so they don't have time. They don't have anyone to take care of that. The older children can just hold the child, nothing else" CNA, IDI 5.

Barriers within the household

In all of the focus groups, mothers raised the issue of not having enough money for complementary foods.

> "We don't have money to buy complementary foods" Mother, FGD 3.

> "What we are going to eat today, we are looking for it today" Mother, FGD 4.

Having a large family and short birth spacing also contributes to this problem because the parents have to provide for all members of the family, not just for the young children.

> "Poverty is the real problem" Mother, FGD 3.

> "Also, some families have a lot of children so they can't take care of all of them properly" Mother, FGD 4.

These responses were confirmed by the in-depth interviews where most of the key informants stated that poverty and insufficient income are problems for complementary feeding.

> "The main problem is the lack of money" CNA, IDI 4.

> "The main problem is the money to buy the food, because you know the people here do not really have big lands to cultivate, most do the *saraka an-tsaha* (casual labor) for their living. So, they are looking today what they will be eating for today and so on" CNA, IDI 3.

Food availability was also cited by many mothers as a difficulty in feeding infants appropriate complementary foods.

> "It depends on what is available. Sometimes you can find colorful [foods], sometimes you can't" Mother, FGD 7.

> "We must live with what is available here in the countryside, you just have to change the way you cook it or how you prepare it" Mother, FGD 5.

Some mothers mentioned their difficulty buying inputs for their agricultural crops that could be used for complementary foods.

> "We don't have money to buy seeds so that we can plant after" Mother, FGD 2.

Lack of inputs for agriculture was also mentioned by the key informants. They also added that households own small agricultural lands, limiting their agricultural production.

> "All of what they are earning goes to buying food, they don't have shovel to work the land, they don't have fertilizer, and they don't have the other tools to do agriculture, seeds, things like that" CNA, IDI 1.

> "They only have small land to cultivate, some just have 5 x 5 m, and with that they can only grow one crop (…); and if they wanted to cook some vegetable soup, they would have to buy all of the other ingredients" CNA, IDI 4.

Consequently, harvest usually does not last until the next season so they have to buy foods.

> "They grow some crops but let's say they harvest in April and by August or September, the rice will be finished already. So, from September until April the following year, they will have to live on *saraka an-tsaha* (casual labor)" CNA, IDI 3.

Barriers within the community

Although most key informants reported that there were no cultural taboos regarding foods given to infants, some rumors were still circulating among the community. For example, infants and young children should not be given beans, eggs, or milk.

> "They [mothers-in-law] would say that the child cannot eat this or that, for example, corn and beans should not be given to children", CNA, IDI 5.

> "They say that children from 6 months to 2 years shouldn't be given onions. Also, milk, they also say that milk should not be given to children. That's what I heard" CNA, IDI 5.

> "We always encourage them to give eggs to their children but they will not give the yolk because it's taboo for the children. Taboos still exist here" CNA, IDI 1.

Maternal enablers of optimal complementary feeding

All of the mothers reported that giving their children adequate complementary foods was important to them. Mothers associated good complementary foods with child growth and health in general. They also mentioned complementary foods give children energy and help with the child's brain.

"So that the child can grow well" Mother, FGD 1.

"[Complementary food is] for physical and mental growth" Mother, FGD 3.

"[Complementary foods] give energy and strength" Mother, FGD 4.

A few mothers reported that foods are important because breast milk is not sufficient for the child anymore.

"Because breast milk is not enough and [complementary foods] completes it" Mother, FGD 7.

"When you work, then the milk is wasting, so it will not be enough for your child's growth" Mother, FGD 4.

The key informants confirmed that mothers generally consider their children's health important.

"Yes, I think so, they realize that [children's health is important]" CNA, IDI 1.

"… people really love their children. They feel for their children when they don't gain weight, when they are malnourished, it's really sad" CNA, IDI 3.

Also, consistent with the survey results, mothers had generally good knowledge regarding complementary feeding. Several mothers mentioned that giving children appropriate foods for their age is important, both in terms of quantity and consistency.

"Because they are still small, they may not digest well what you eat at home so you have to cook for them separate foods, foods that are okay for their age because they are still young" Mother, FGD 1.

"For example, corn or rice, so we have to smash them and make them in form of porridge", Mother, FGD 4.

"Don't give the child too much food, he won't digest" Mother, FGD 5.

Mothers also stated that children should be given nutrient-dense foods including meat, fish, vegetables, dairy, fruits, and rice.

"Food in form of porridge from 6 months until 11 months, because their stomach can't tolerate", Mother, FGD 7.

"Foods with a lot of vitamins…potatoes, carrots, fish", Mother, FGD 1.

Enablers at the household level

Almost all of the key informants mentioned that although generally mothers decide what foods to give to their children, they are supported by their husbands. Fathers or mothers-in-law and other members of the family, if present, are reported to advise on what to give the child but the decision is made by the mother.

"It's always the mother" CNA, IDI 3.

"They make their own decision but for those who have parents-in-law, they can just advise from outside on what should be given to the child" CNA, IDI 4.

"The father can help advising the mother about how to improve the foods" CNA, IDI 2.

Enablers at the community level

Another potential enabler is the positive relationship between the mothers and the CNAs. All of the mothers in the focus groups typically would ask the CNAs for advice on child feeding.

Their proximity and their knowledge of child health as well as their training are common reasons evoked by the mothers on why they ask the CNAs first.

> "She is close to us so we only ask her" Mother, FGD 7.

> "Because they [CNAs] know a lot about mothers and child" Mother, FGD 4.

A few mothers also ask the local medical staff and some will get nutrition information from the health booklets provided by the national community nutrition program.

> "Because we don't have the knowledge so we have to ask so that we do not do the wrong thing" Mother, FGD 2.

> "We look at the booklet so there we can know" Mother, FGD 6.

The key informants reported similar responses.

> "Yes, most of the times, they will ask us", CNA, IDI 4.

> "… as I said we are close to them so they talk to us first. They would only talk to the other community members after talking to us, telling them what we told them. So, they would discuss between them" CNA, IDI 3.

Lastly, a few mothers in the focus groups would seek advice from friends or the elders in the family regarding child feeding, which was confirmed by the key informants.

> "Older people should know so we should ask them" Mother, FGD 3.

> "If you are at home giving food to your child, you'll have to ask your parents because they are closer" Mother, FGD 2.

Answers from the key informants were similar.

"Yes, they do ask them [friends] but they usually come here first" CNA, IDI 1.

"They will ask their own parents first" CNA, IDI 2.

4. Discussion

Child undernutrition rates were very high in the Vakinakaratra region, especially for stunting (69.4%), which was even higher than the national average of 42% (MICS). Stunting rates also were higher than in the other areas within the central region of Madagascar [17, 18]. However, our study focused on the 6 – 23 months age group, which has been reported to have lower mean LAZ compared to the older children [19]. Nevertheless, this considerably high rate of stunting in children under the age of two needs immediate attention as it is recognized by WHO as a serious public health concern [20]. Underweight prevalence was still high (23.4%), although lower than the national average of 26% and is also a concerning problem [20].

The relatively good maternal knowledge of complementary feeding may be attributed to the regular nutrition education sessions conducted at the community nutrition sites in each fokontany led by the CNAs. In fact, 69% of the mothers reported getting nutrition information from the CNAs and other medical staff. However, 36.1% still did not think that infants younger than 6 months should be exclusively breastfed. Reinforcing the recommendation of exclusive breastfeeding during the first 6 months among lactating mothers and first-time mothers should be emphasized in the region. Breast milk is nutritionally adequate and is the safest food source for infants of that age [2, 21]. Additionally, exclusive breastfeeding provides protection against infections, reduces risk of infant mortality, and in the long-term, can improve cognition.

Most mothers also knew the importance of diverse meals for infants and young children but only about half thought that infants should be given vegetables daily. Mothers in the region understood the importance of giving adequate complementary food to growing infants and young

children, and qualitative studies from Kenya [22], Ethiopia [23, 24], and Ghana [25] reported similar findings. Also, 33.2% did not think that infants should be given fruits daily. Emphasizing the importance of feeding children fruits and vegetables may be needed to increase mothers' knowledge.

Complementary feeding practices generally were suboptimal, with minimum meal frequency being the highest at 71.6%, which is similar to the findings from the Comprehensive Food Security and Vulnerability Analysis in 2011 [9]. In our study, early two thirds of the infants were not fed a diverse and adequate diet. Results from the 2018 MICS surveys (31%) and the 2012 Millennium Development Goals (MDG) (33.6%) monitoring surveys reported lower proportions of children under 2 achieved the minimum diet diversity in the Vakinankaratra region. Although the proportion in the current study (35.8%) is higher than the national rates of 25%, there is still a potential and need to increase the diversity of complementary foods in the region given its high agricultural productivity.

The food group most commonly given to infants was grains, mainly rice. Also, green leafy vegetables, as well as legumes and nuts, mainly beans, were frequently given. A relatively high proportion (51.7%) of infants in the region consumed foods from the meat, poultry, and fish category. However, most infants were given small fish (43.2%) rather than meat or poultry (14.1%) because during the time of data collection, fish was readily available. These small fish from the rice paddies are sold by many farmers around rice harvesting time at an affordable price. Thus, the proportion of infants who ate flesh foods is expected to be lower during other seasons, for example during planting and lean season in January to March [26]. Yogurt was the most common dairy product given to infants in contrast with results from the Menabe (central West coast) and the Alaotra Mangoro (central East coast) regions where only 16.3% and 6.3% of children under five consumed dairy products [27]. Because the dairy industry of Madagascar is concentrated in the Vakinankaratra region, milk and dairy products are more available compared

to the other regions. Similar to the Menabe region, the food group with the lowest consumption was eggs, consumed by only 3.3% of the children [27]. Although half of the households had poultry, if eggs are produced, they are sold for income rather than consumed. Also, there are still beliefs about eggs yolk being a heavy food and not appropriate for young children.

Only consumption of iron-rich foods was associated with lower odds of being underweight. Stunting was not associated with any of the complementary feeding indicators. These results suggest that improvements in complementary feeding alone are not likely to prevent stunting in children under 2 years in the Vakinankaratra region. Similar results have been reported in cross-sectional studies where only selected IYCF indicators were associated with better child growth [4-6, 28].

Nevertheless, in infants 9 – 11 months, eating more diverse foods was associated with lower risk of being stunted. This group may be particularly vulnerable because the drop in LAZ is more dramatic compared to the other age categories (6 – 8 and 12 – 23 months) according to the global child growth trajectory [19, 29]. Additionally, compared to children 12 – 23 months, infants 9 – 11 months are given less diverse foods (mean DDS 2.97 compared to 3.18) in our sample. The nutrient gap to be filled by complementary foods in the 9 – 11 months age group may be greater than in the younger group (6 – 8 months), putting them at a higher risk of deficiency. These findings warrant the need for further study of the nutrient adequacy of complementary foods in different age groups for children younger than two in the Vakinankaratra region.

The limited associations found between child anthropometrics and improved IYCF practices does not undermine their crucial roles but rather emphasizes the multifactorial aspects of child undernutrition. Besides feeding practices, multiple basic, underlying and individual factors influence child growth directly or indirectly [30, 31]. Nevertheless, efforts are still needed

to improve IYCF practices in the Vakinankaratra region. As greater knowledge was associated with better practices, continuing the nutrition education sessions at the community sites as part of the National Nutrition Plan is needed. However, coupling the educational sessions with interventions addressing the identified barriers of complementary feeding practices potentially would yield even greater impacts on child undernutrition.

Perceived lack of breastmilk and considering certain foods as heavy were identified maternal barriers for optimal complementary feeding. Lack of breast milk has been reported in various country settings as a reason to give infants other foods early [32-36]. Mothers said that the infants were fussy or still hungry even after being breastfed. Some mothers believed that their milk production decreased because of their workload.

Breast milk contains all the needed nutrients for infants' growth during the first six months of life. Except in the case of severe maternal undernutrition, most components of breast milk should not change much during the lactation period [2, 37, 38]. Because breast milk production is more dependent on breastfeeding frequency and length of each feeding episode than on maternal diet, increasing support for lactating mothers will be helpful in delaying early introduction of complementary foods [39]. Support can be material (financial, food, resources), emotional (encouragement and positive reinforcement), or practical (help with household chores). Any kind of support has been shown to improve breastfeeding practices [40], particularly paternal support [41].

Some mothers avoided giving eggs, beans, and sometimes milk as complementary foods because they believed young children could not tolerate these foods. Mothers also were aware of their infants' limited ability to digest foods saying that foods should be appropriate for the infant's age. Not giving children certain foods on the basis of being "heavy" or "hard" has been also reported in Ethiopia [23], Bangladesh [33], Mexico [42], and Senegal [43]. Some of these

foods, particularly eggs and beans, are nutrient-dense and should be included in the infant's diet to complement breast milk. In Madagascar, nutrition education sessions would be effective in addressing such maternal barriers because of the mothers' trust in the CNAs. Emphasizing the importance of a diverse diet and providing examples of how to prepare these commonly avoided foods to be appropriate for young children may encourage the mothers to include them in complementary foods.

Mothers also mentioned not having enough time and being tired because of agricultural work as a problem. Especially during the lean season, most mothers had to help their spouses provide for the family by engaging in casual labor. In addition, they also need to take care of household chores and the children. Encouraging the engagement of fathers in child care activities has the potential to reduce maternal workload by sharing the responsibilities in the household. Greater fathers' involvement has been associated with better child feeding practices in various low- and middle-income countries (MICs) [44-48].

Similar to other LMICs, food insecurity and lack of income were additional constraints to appropriate complementary feeding [22, 23, 32, 34, 36, 49, 50]. This highlights the central role of agriculture in nutrition, because agriculture is a source of both income and food for rural households [51]. Due to the high seasonality of agricultural production, foods are only available during certain periods of time, mainly during the harvest and post-harvest seasons, which considerably limits food supply. Also, land access is limited because most households are smallholder farmers owning on average 43.9 square meters in our sample. In addition, it is very common for farmers to sell all of their fresh produce during harvest season, and then buy food later for consumption. Integrating agriculture and nutrition by addressing food security while emphasizing the importance of diverse, nutrient-dense foods for infant growth and development has potential benefits. Interventions combining homestead food production and behavior change

strategies for complementary feeding practices reported positive results on vegetable production as well as children's nutritional status [52, 53].

In addition, key in improving complementary feeding practices is the support of other family members to the mothers in deciding what foods to give the child. Greater women's autonomy and more agency in decision making over child nutrition have been associated with improved feeding practices and child nutritional status [54-57]. The mothers' trust in the CNAs and their overall positive relationship is also an important facilitator for optimal feeding practices. Ensuring that the CNAs, as frontline workers, are well trained in providing the needed services to the population at the community nutrition centers is crucial. Conducting regular trainings for the CNAs, not only on the technical aspects of child feeding and nutrition, but also on interpersonal communication and counseling is needed.

To a lesser extent, mothers also consult their friends and the elders regarding complementary foods. This could be either a barrier or an opportunity for optimal feeding practices, depending on the knowledge and the perceptions of the elders and the community members. Grandmothers' knowledge has been shown to influence maternal feeding practices in various LMICs [58-60]. Involving grandmothers when designing interventions may reinforce the messages targeted to the mothers regarding appropriate feeding practices. Also, a peer-to-peer model [61], where a group of mothers share information among themselves in addition to the traditional sessions by health workers, could increase the effectiveness of interventions. Peer counselling interventions reported promising results in promoting optimal breastfeeding practices [62] and reducing child undernutrition [63, 64].

The identified barriers and enablers are valuable information to be used to design future interventions in the Vakinankaratra region. Such insights regarding the local context are key factors to consider especially for behavior change interventions [65].

The cross-sectional design of this study, which does not allow for causal association between child feeding knowledge, practices and child growth is a limitation. However, such studies will be difficult to conduct because of the multifactorial aspects of undernutrition. In addition to the suboptimal complementary feeding practices, several underlying factors are likely to contribute to these high rates of child stunting and underweight. We only collected data from communities covered by the national community nutrition program, which are assumed to be more vulnerable than communities without community nutrition sites. Also, the timing of our data collection spanned between the end of the lean season and the beginning of harvest season, which may influence the quantity and the quality of complementary foods given to infants. Lastly, recall bias and social desirability are inherent limitations for this type of research. For the qualitative questions, we conducted in-depth interviews to confirm the answers given by the mothers in the focus groups.

However, this study is the first to assess maternal knowledge and practices of complementary feeding and their association with child anthropometrics in the Vakinankaratra region of Madagascar. And to the best of our knowledge, this study is the first to identify barriers and enablers of appropriate feeding practices. Also, the mixed-methods design provides a more comprehensive evaluation of the complementary feeding situation and how it relates to child nutritional status in a region with limited data, but with a high burden of undernutrition.

5. Conclusion

Stunting and underweight rates are very high in children younger than two years in the Vakinankaratra region. Although only a few IYCF indicators were significantly associated with child growth, efforts are needed to improve complementary feeding practices. The identified barriers and enablers support the need for integrating agriculture with a behavioral change component to improve feeding practices. Also, strengthening the local community health worker structure and training has potential benefits.

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Table IV.1. Focus group discussions questions and interview guide.

Focus Group Discussion Questions
1. What kinds of complementary foods do you give your child?
2. How important is it to you that your child has adequate complementary foods?
3. How do you decide when to give the child complementary foods?
4. How do you decide what to give the child complementary foods?
5. If you have questions about complementary foods, who do you ask?
6. If you want to change the foods you give your children, what would make it difficult to do so?
Interview Guide
1. In the household, who decides what food to give to the child?
2. If parents have questions about complementary foods, who do they ask?
3. If parents wanted to feed their child better, what would make it difficult to do that?

Table IV.2. Characteristics of the study population.

Variables	n	Frequency (%) or mean (SD)
Maternal characteristics		
Maternal age	389	27.4 (6.8)
Maternal occupation		
Doesn't work/housewife	31	8.0
Farmer	308	78.8
Office or part-time job	52	13.3
Highest level of education		
None	18	4.6
At least some primary	204	52.2
At least some secondary	118	30.2
Higher	48	12.3
Missing	3	
Antenatal care attendance		
Less than 4	113	28.9
4 or more	278	71.1
Exposure to radio over past week		
Didn't listen to radio	217	56.1
Once or twice	45	11.6
Almost every day	125	32.3
Missing	4	
Source of nutrition information		
Nowhere	66	16.9
Family and relatives	21	5.4
Media	6	1.5

CNA and medical staff	28	7.2
More than one source	270	69.0
Household characteristics		
Household size	384	4.9 (1.9)
Socioeconomic status		
Low	123	33.4
Medium	123	33.1
High	123	33.4
Missing	23	
Child characteristics		
Child age (months)	391	14.1 (5.2)
Age category		
6-8 months	72	20.2
9-11 months	76	21.3
12-23 months	243	62.1
Sex		
Male	197	50.4
Female	194	49.6

SD: standard deviation

CNA: Community Nutrition Agent

Table IV.3. Undernutrition prevalence in the study sample.

Indicator	N	Prevalence (%)	Mean z-score (SD)
Stunting	268/385	69.4	-2.4 (1.4)
Underweight	88/376	23.4	-1.2 (1.1)
Wasting	12/376	3.2	0.1 (1.2)

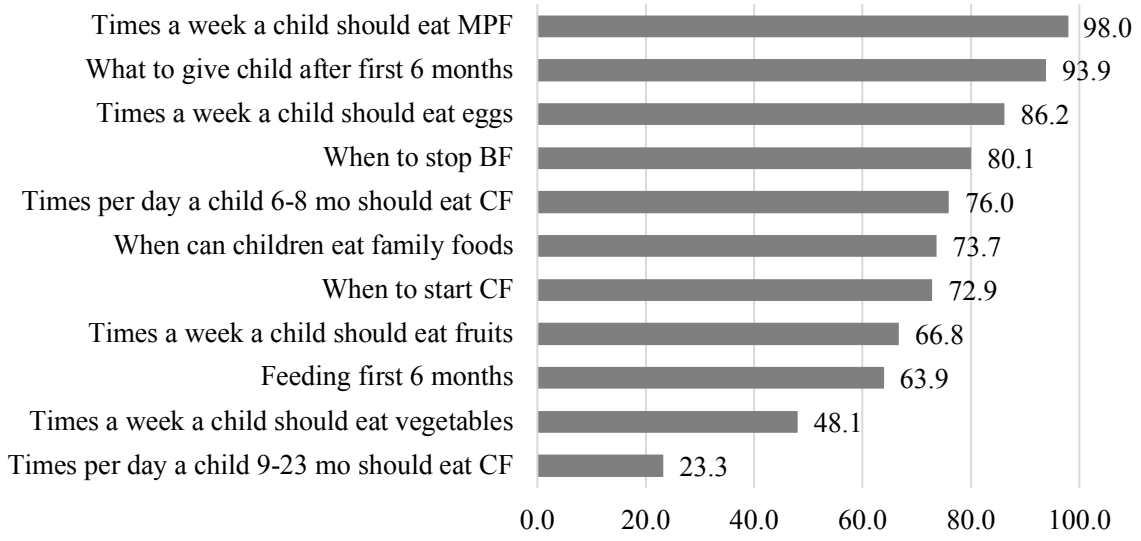

Figure IV.1. Maternal complementary feeding knowledge (% of correct responses).

MPF: Meat, poultry, and fish; BF: breastfeeding; CF: complementary foods.

Table IV.4. Correct responses for maternal complementary feeding knowledge questions.

Question	Expected responses [13]
Feeding first 6 months	Breast milk only
When to stop breastfeeding	After 2 years
When to start complementary feeding	At 6 months
What to give child after first 6 months	Soft and semi-solid foods
Times a week a child should eat meat, poultry, and fish	Any frequency (vs. cannot eat)
Times a week a child should eat eggs	Any frequency (vs. cannot eat)
Times a week a child should eat vegetables	Every day
Times a week a child should eat fruits	Every day
Times per day a child 6 – 8 months should eat complementary foods	2 times
Times per day a child 9 – 23 months should eat complementary foods	3 times
When can children eat family foods	1 year

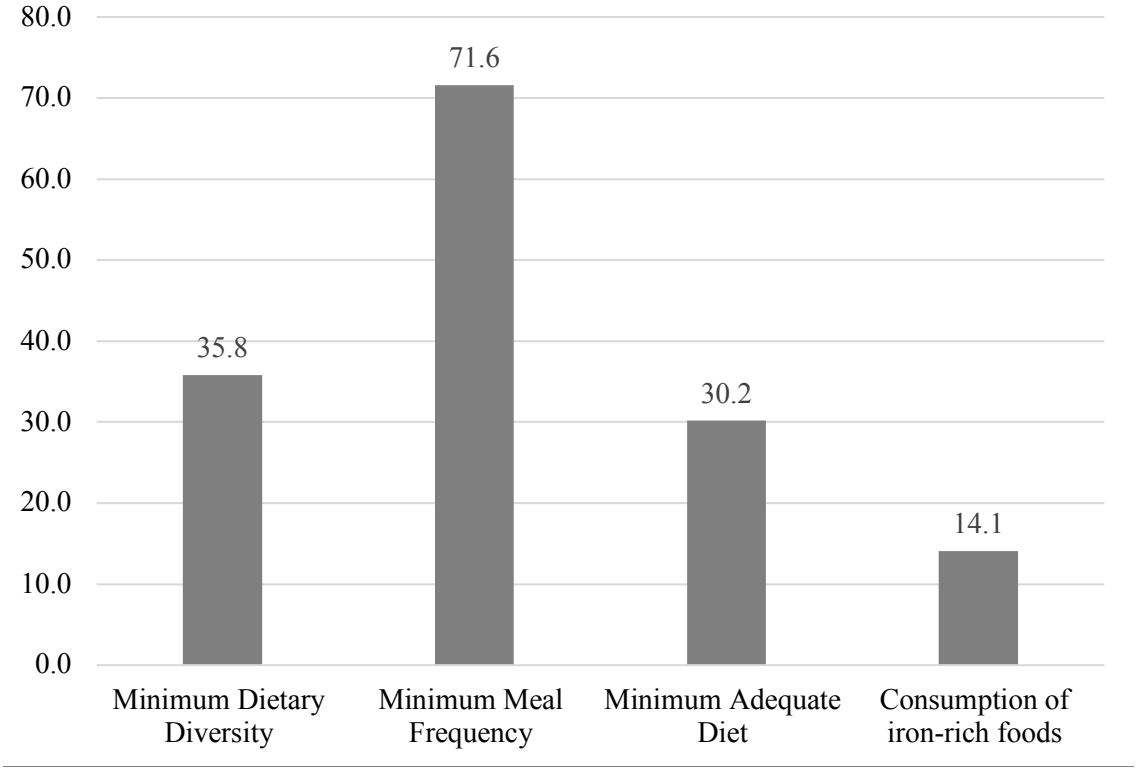

Figure IV.2. Proportions (%) of children meeting the WHO Infant and Young Child Feeding indicators in the Vakinankaratra region (n = 391).

Table IV.5. Association between maternal knowledge and complementary feeding practices.

CF indicators	COR (95% CI)	AOR (95% CI)[1]
Minimum dietary diversity	1.3 (1.3 – 1.5)***	1.2 (1.1 – 1.4)*
Minimum meal frequency	1.2 (1.0 – 1.5)*	1.2 (1.0 – 1.5)*
Minimum acceptable diet	1.3 (1.1- 1.6)***	1.2 (1.1 – 1.5)**
Consumption of iron-rich foods	1.5 (1.2 – 1.9)***	1.5 (1.2 – 1.8)***

CF: Complementary feeding, COR (95% CI): crude odds ratio with 95% confidence interval, AOR: adjusted odds ratio with 95% confidence interval

[1]Models are adjusted for clustering and for age at first birth, head of household, listened to radio, number of living children, food security score

*p < 0.05, **p < 0.01, ***p < 0.001

Table IV.6. Association between complementary feeding practices and child nutritional status.

	CF indicators	Minimum dietary diversity	Minimum meal frequency	Minimum acceptable diet	Consumption of iron-rich foods
Stunting	COR (95% CI)	0.9 (0.6 – 1.4)	1.7 (1.0 – 2.7)*	1.0 (0.6 – 1.7)	0.5 (0.3 – 1.0)
	AOR (95% CI)[1]	0.9 (0.5 – 1.4)	1.3 (0.7 – 2.6)	1.0 (0.5 – 1.8)	0.7 (0.3 – 1.5)
Underweight	COR (95% CI)	0.9 (0.6 – 1.3)	1.0 (0.6 – 1.7)	1.0 (0.7 – 1.5)	0.3 (0.1 – 0.7)*
	AOR (95% CI)[2]	0.8 (0.5 – 1.3)	0.6 (0.3 – 1.2)	1.0 (0.7 – 1.5)	0.3 (0.1 – 0.7)*
Wasting	COR (95% CI)	0.9 (0.3 – 2.9)	0.5 (0.2 – 1.7)	1.1 (0.3 – 3.8)	1.2 (0.2 – 5.9)
	AOR (95% CI)[2]	0.9 (0.2 – 3.3)	0.4 (0.1 – 1.9)	1.1 (0.3 – 5.0)	1.6 (0.3 – 7.8)

CF: Complementary feeding, COR (95% CI): crude odds ratio with 95% confidence interval, AOR: adjusted odds ratio with 95% confidence interval

[1]Models are adjusted for clustering and for child age, maternal height, child sex, birthweight for LAZ

[2]Models adjusted for clustering and for child age, child sex, and birthweight for WAZ and WLZ

*p < 0.01

Table IV.7. Association between maternal knowledge of complementary feeding and child nutritional status.

	COR (95% CI)	AOR (95% CI)[1]
Stunting	1.0 (0.9 – 1.2)	1.0 (0.8 – 1.2)
Underweight	0.8 (0.7 – 0.9)**	0.8 (0.6 – 0.9)*
Wasting	0.8 (0.6 – 1.1)	0.8 (0.5 – 1.1)

CF: Complementary feeding, COR (95% CI): crude odds ratio with 95% confidence interval, AOR: adjusted odds ratio with 95% confidence interval

[1]Models are adjusted for child age, maternal height, child sex, and birthweight for LAZ. Models adjusted for child age, child sex, and birthweight for WAZ and WLZ

*p < 0.01; **p < 0.001

Table IV.8. Participant characteristics in the focus group discussions.

Variables	N	Frequency (%) or mean (SD)
Age		23.3 (6.3)
Occupation		
Doesn't work	2	4.3
Farmer	42	91.3
Other	2	4.3
Highest education level		
At least some primary	16	37.2
At least some secondary	19	44.2
Higher	8	18.6
Household size		5.1 (2.2)
Antenatal care attendance		
Less than 4	12	26.1
4 or more	34	73.9
Radio listening		
Not listening	20	43.5
Once or twice a week	9	19.6
Almost every day	17	36.9

SD: standard deviation

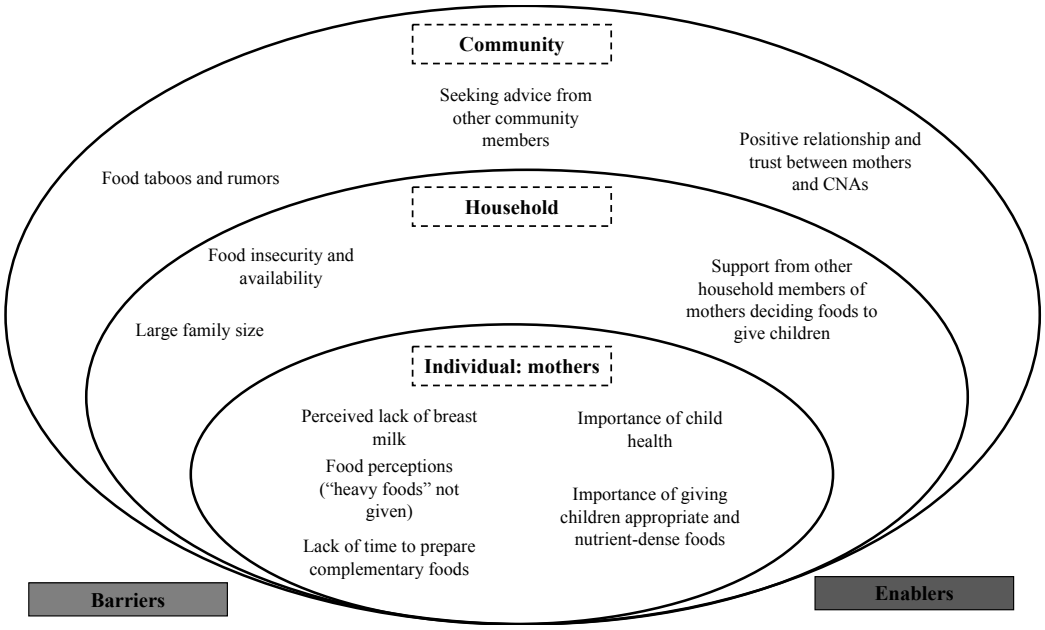

Figure IV.3. Barriers and enablers of optimal complementary feeding practices in the Vakinankaratra region of Madagascar.

CHAPTER V

CHARACTERIZING FATHERS' INVOLVEMENT IN CHILD CARE ACTIVITIES: PERCEPTIONS FROM CAREGIVERS AND THE COMMUNITY IN THE HIGHLANDS OF MADAGASCAR

Abstract

There are limited studies investigating the roles and extent of fathers' involvement in child care in Madagascar. The aim of this study was to explore the community's perceptions, attitudes, and practices regarding fathers' involvement in child care using qualitative methods. A total of 10 focus group discussions were conducted: seven among mothers of children aged 6 – 23 months (n = 46) and three among fathers (n = 17). In-depth interviews (n = 8) were also conducted among key informants. Discussions and interviews were audio-recorded and the verbatim transcripts in Malagasy were translated in English. The thematic analysis approach was used to analyze the data. Provision of financial and material support and teaching and playing with the child were the main perceived roles of fathers. In practice, fathers spend their time alone with their children playing and holding them when their wives are unavailable. Busy schedule and separation due to work was the major barrier to fathers' involvement. Traditional gender roles on child care in which the mother is seen as primarily responsible for the child were salient across the data.

Consequently, both men involved in child care activities and their wives are often criticized by the community. There is interest from both mothers and fathers in getting men more involved in child care. Interventions to shift the community perceptions on the divided responsibilities between fathers and mothers may be needed.

1. Introduction

Madagascar is among the countries with the highest burden of undernutrition; 49% [1] of the children under five years are stunted and 26% are underweight [2]. Moreover, poverty is widespread with 77.6% of the population living under $1.9 a day [3]. These high stunting and poverty rates increase dramatically the risk of poor development of almost half of Malagasy children [4]. Appropriate child care practices are critical in promoting optimal child growth and development [4-6]. These include food preparation and feeding, psychosocial stimulation, hygiene practices, and care during illness [7]. Similar to other sub-Saharan countries, such activities are often performed by the mothers as they are regarded as the primary care providers [8-10].

Fathers' perceived roles typically include the provision of financial and logistical resources for the family [8]. Consequently, most interventions aiming to improve feeding practices and to promote child development are targeted to mothers. However, there is emerging evidence on the positive effects on child nutrition outcomes of expanding fathers' involvement beyond their traditional roles in low- and middle-income countries (LMICs). Nutrition education sessions targeted to fathers improved child feeding practices in Kenya, Ethiopia, and Vietnam [11-13]. The positive effect of paternal involvement on child development outcomes has been well documented, although most of the studies were conducted in high income countries. Children whose fathers are more consistently engaged have higher cognitive scores [14-18], better emotional regulation [15], and improved language skills [19, 20]. Therefore, increasing involvement of fathers in child care has the potential to contribute in the efforts of reducing child undernutrition and promoting child development in LMICs. Additionally, engaging fathers in child care activities can also alleviate the workload of mothers, which is in line with the United Nations' Sustainable Development Goal 5: achieve gender equality and empower all women and

girls [21]. Designing and implementing such interventions requires a strong understanding of the local social context and culture.

In Madagascar, parental perception of fathers' roles and participation in child care has not been well studied. Thus, the purpose of this study was to explore Malagasy parental perceptions, attitudes, and practices regarding fathers' involvement in child care using a qualitative approach. Our research questions included: 1) what are the perceptions of fathers' responsibility in child care? 2) how are fathers engaged in child care? 3) what are the barriers to fathers' involvement? 4) what are the perceptions of the community regarding involved fathers? Results of this study will provide valuable insights in designing future programs and interventions aiming to increase fathers' engagement in child care in Madagascar. In this study, father involvement is defined as paternal participation in direct interactions with the child (feeding, holding, playing, bathing, etc.) as well as indirect responsibilities related to child care (providing, cooking, etc.).

2. Methods

Study participants

This qualitative study was conducted in two districts of the Vakinankaratra region of Madagascar, Antanifotsy and Antsirabe II in April 2019. Participants included mothers (n = 46) and fathers (n = 17) of 6 – 23 months children for the focus group discussions (FGDs). For the mothers, seven FGDs were conducted and three FGDs were held for fathers. Purposive sampling was used to select fokontanys (smallest administrative unit) with experienced community nutrition agents (CNAs). Then, CNA selected participants who would be willing to speak and contribute to honest discussions regarding child care and fathers' involvement. When FGD were conducted for both mothers and fathers in the same fokontany, participants had to come from different households to avoid conflict and potential bias. Individual in-depth interviews (IDI)

were conducted among CNA's (n = 6), a nurse, and a field program monitor who works for an non-governmental organization (NGO) implementing the activities of the national community nutrition program. The key informants were included to add more perspective and dimension to the data collected from the mothers and fathers. Key informants constantly interact with parents and live within the community so they can provide valuable information regarding community perceptions and attitudes.

Data collection

FGD questions and the interview guide were developed based on previous relevant research and the questions the researcher wanted to explore (table V.1). Questions were reviewed by the doctoral committee members before translation in Malagasy. The translated questions were reviewed by Malagasy native speakers: two mothers and two fathers of children younger than five years. No formal revisions were made to the questions before data collection. As data collection progressed the researcher reflected on the responses given by the participants and the discussion after each FGD. The researcher changed the way the questions were framed and asked as appropriate to the local context. The same approach was used for the interviews. FGDs and IDIs were conducted in the local language, Malagasy, and were audio-recorded. To achieve saturation, the researcher used probing questions during the interviews and FGD. Saturation was reached when no new information was being shared during the FGDs or IDIs.

Data analysis

FGDs and IDIs were transcribed verbatim by a native speaker and transcriptions were back-translated in English. A thematic analysis approach was used to analyze the data [22, 23]. First, the researcher familiarized himself with the data by actively reading the transcripts and the

field notes. Codes were developed from patterns found in the data. Two teams of researchers coded the data using NVivo v. 12 (QSR International, Melbourne, Australia). The codes were cleaned by the researcher and reviewed by the team after the coding process. Codes with similar patterns were grouped into themes in order to answer the research questions. Theme development was also conducted as a team. Discrepancies were discussed and resolved when researchers disagreed during coding or during the development of themes. There was less than 5% initial disagreement during data analysis. Field notes were used throughout the data analysis and the writing process to add context to the data.

Trustworthiness/reliability

To increase the trustworthiness of the results, triangulation strategies were used [24]. Information was gathered from different sources: mothers, fathers, and key informants. Methods triangulation was also used by collecting data from both group discussions and semi-structured interviews. Additionally, data were collected from participants from different communities in the rural areas of the Vakinankaratra region. Having multiple perspectives of participants living in different areas may increase the reliability of the data and may also help achieve saturation. Trustworthiness and reliability were further reinforced by the involvement of two other researchers during the development of codes and themes.

Ethics

This study was approved by the Oklahoma State University Institutional Review Board and by the Ethics Committee of Ministry of Public Health of Madagascar. The purpose of study was explained to eligible participants and they were given opportunity to ask questions about their voluntary participation. Study participants signed the informed consents before any data

collection activity. Participants were compensated for their time after the FGD and the IDI with iodized salt (250 g) and cooking oil (1/2 liter).

3. Results

Table V.2 summarizes the descriptive characteristics of the study participants. Fathers (31.7 years) had a higher mean age than mothers (23.3 years). Most of the parents were farmers and more mothers had received secondary education than fathers. Fathers in the sample tended to listen to radio more than the mothers.

Perceptions of fathers' responsibility in child care

Fathers perceived their responsibilities as providing financial resources (table V.3). In all of the focus groups, fathers mentioned providing financial and material support for the household as their main responsibility. Fathers perceived that their responsibility was limited to finding money for buying foods and clothes for their families and for health care. Also, fathers think they are responsible for the household's material assets such as agricultural tools and other items in the house. Interviews with the key informants confirmed the fathers' views.

"So, providing, looking for money" Father, FGD 2

"Most of the time, men think that they should just provide" CNA, IDI 5

Several fathers mentioned that they were responsible to help their wives in various child care activities such as bathing, cleaning, and feeding the child. Fathers think they should help only when mothers were busy with other chores. Directly helping the mothers with household chores was also perceived as a fathers' responsibility by some fathers.

> "For me when the mother is busy and if the baby is throwing up, then I go and clean him up" (Father, FGD 1)

> "When you are home, you both have to fetch water because you both are tired. That should be normal if you love you wife, you wouldn't stay there doing nothing because both of you are tired after work" (Father, FGD 3)

In addition, caregiving was not seen by the community as the fathers' responsibility. The mother is the primary caregiver, but the father may help if he is willing and available.

> "Yes, he [the father] does not take care of the child directly but when he has time, he can take the child and leave the woman to take care of the house" CNA, IDI 4

Fathers also mentioned that they were responsible for teaching and playing with the child. One father made the connection between play and development. Several fathers in three focus groups mentioned supervising and advising as their roles in supporting their wives in raising their children. Supervision include ensuring that the mothers gave nutritious foods to the child and had appropriate hygiene practices. A few fathers in two focus group discussions mentioned consoling the child in the absence of the mother as an important responsibility.

Current fathers' involvement in child care activities

Child home stimulation, spending time with the child, food preparation and feeding, and supporting the mothers with household chores are the reported activities related to child care in which fathers are involved (table V.4). Most fathers in the FGDs mentioned playing with and teaching their children regularly. Teaching included talking, walking, and even disciplining. Fathers were also engaged in various play activities with their children, from playing soccer to

dancing with them. Also, fathers were aware of the connection between playing and teaching and child development. Often, they reported the importance of helping the child's mind to grow. Responses from the mothers were similar as playing and teaching the child were the main activities they saw their husbands doing with the children.

> "They [fathers] teach the baby how to talk too" Mother, FGD 7
>
> "I teach him to say "dada" (father in Malagasy) or something like that" Father, FGD 2
>
> "They [father and child] play soccer" Mother, FGD 3
>
> "I play with him [child] to open his mind" Father, FGD 1

Additionally, several fathers mentioned they frequently hold the child, walk around the neighborhood with the child and clean the child on certain occasions.

> "He [the father] takes him [the child] and they walk around, he shows him around" Mother, FGD 1

Fathers also mentioned that they were involved in various child care activities such as changing clothes or bathing. Mothers confirmed in the FGD that they husbands were participating in these activities when they were busy.

> "[My husband] washes the baby's hands when dirty" Mother, FGD 2

Some fathers reported being involved in cooking and feeding the child as well, but when their wives are not available. Discussions with mothers confirmed that fathers cook and feed the child sometimes, when they are busy. Also, fathers were still partly relying on mothers when they participate in such activities.

> "For me, it's very similar, if I am home then the mother will show me what foods the baby should be eating so I learn from her and when she is not there I do it" Father, FGD 2

Only a few fathers mentioned helping their wives do household chores and agriculture work as part of their support in raising the child.

From the FGD, a few fathers expressed interest in getting more involved in child care activities, but only when they are not busy. One father mentioned that participating more with tasks related to his child will build stronger bonds. Almost all mothers in the FGD were enthusiastic about the prospect of fathers' involvement. Mothers stated that the child would be healthier and stronger when fathers are participating more in child care activities. Moreover, mothers reported they would be relieved, happy, and would have fewer chores as well as more time to do other chores.

> "For me, if I have time, just as he said earlier because of work. But if I have time and I am home, then I must take care of the child but when I am away, then the mother will do what she can" Father, FGD 1

> "If he [the father] is more involved, the baby will be healthier and stronger because even his [the child] food will be appropriate" Mother, FGD 1

> "Because if he [the father] holds the baby, we can do all of those things…we could wash clothes, sweep the yard, talk more to the baby, if he is there holding the baby or if he participates more" Mother, FGD 4

Only a few fathers mentioned activities they were interested in doing more with their children, including playing and walking around more. Mothers also wanted their husbands to be more involved in various activities such as playing with the child, holding the child more, and participating more in feeding. Several mothers wanted their husbands to help more with household chores including working on their own agriculture.

> "I would like to make him [the child] some toys if I had time, because they like those things, and it makes their mind grow" Father, FGD 2

> "I would like to take my child around but I don't have time, I would like to take her around the fields but there is no time so I can't do it" Father, FGD 1

> "I would ask him [the father] to prepare the foods for the baby and feed the baby after" Mother, FGD 7

> "I would ask him to help around the house" Mother, FGD 7

Barriers to fathers' involvement

Work and related factors, gender role stereotypes, lack of willingness, and not being prepared were identified barriers of fathers' involvement in child care (table V.5). Both fathers and mothers in their FGDs stated that fathers had limited time to take care of the child because of their work and their schedule. Men also engage in casual labor in agriculture, and they work for longer periods than women, usually the whole day. Thus, even those who are willing will only have time in the evening and the weekends to interact with the child and give support to the mother.

> "He is the one who looks for money so he doesn't have time" Mother, FGD 6

> "The main problem is, as mentioned earlier, our schedule, our work schedule" Father, FGD 3

In a few communities, several men work in larger cities or in locations where there is a high demand for a physical workforce. Men will leave their homes for long periods ranging from 2 weeks to 9 months to work because the pay is better than casual labor.

> "The first thing is time because some children are even scared of us when we come back home, they are scared because they don't recognize us" Father, FGD 2

Also, fathers reported being tired from work in the evening so they don't want to take care of the child or be involved with additional child care activities, which was confirmed by several mothers in the FDG. Almost all of the key informants also stated that fathers being tired from work is one of the main barriers to their involvement.

> "They are tired from work, from looking for money so they are very tired and cannot take care of the child in addition" CNA, IDI 6

Traditional gender roles regarding child care were also identified as barriers of fathers' involvement. Mothers mentioned that caregiving is seen as the mothers' job, and the father may take care of the child only when they are not available. Several key informants confirmed these perceptions by saying that women are expected to take care of the child. In line with the mothers' and the key informants' responses, fathers stated that they are providing already and should not be involved much in caregiving activities, which are women's responsibilities.

> "You are the mother so you have to take care of the baby" Mother, FGD 1

> "So, there are fathers who are really saying that the women are the ones who take care of the children" CNA, IDI 2

> "Those [child care activities] are women's job but the men just advise" Father, FGD 3

Several mothers in the majority of the FGD commented that fathers were not willing to be involved in child care activities. Laziness was also mentioned to be a barrier of involvement. Some mothers reported that fathers will not do anything even if they are asked. According to a

few mothers, some fathers will pretend not to know how but they will take care of the child when the mothers are not available. Several key informants also provided similar responses as some fathers are not willing to be involved in child care activities. Interestingly, nothing similar was discussed in the fathers' FGD.

> "No, they [fathers] don't say anything but whenever you ask him [the father] to feed the baby, he will just say no" Mother, FGD 4

> "I think they [fathers] know but they just won't do it" CNA, IDI 3

However, several mothers also believed that their husbands were unprepared to take care of the child. Several mothers mentioned that some fathers do not know how to take care of infants or how to perform specific activities such as cooking or feeding. The key informants commented that taking care of infants is not in the fathers' habits, so they don't do it.

> "For mine, it's because he doesn't know how to prepare food that he doesn't do it" Mother, FGD 3

A few mothers reported that fathers are not involved in child care because they are irritable, especially after work so they do not want to be bothered, and some are worried. A father in the FGD mentioned that when he is worried, he did not want to be near his child.

Community perceptions of involved fathers and their wives

Three themes were extracted including traditional gender roles regarding child care, perceptions of involved fathers, and attitude towards the wives of engaged fathers (table V.6). Similar to the parental perception of fathers' responsibility and the barriers of involvement, the community considers caregiving as the mothers' job.

> "[They will say] That's [caregiving] for the women" Mother, FGD 5

> "So, the people are saying that those [child care activities] are women's work, and if a man does those, they would start gossiping about it" Nurse, IDI 8

Several mothers and fathers in the FGD mentioned that such comments come mostly from other fathers. If men participate in child care activities or help their wives with household chores, their fellow fathers and the other members of the community will tease them. Men engaged in child care activities are usually seen as weak or fools or controlled by their wives. Mothers and the key informants reported that other men are the members of the community who are the most critical towards involved fathers.

> "That he [the father] is defeated by his wife" Mother, FGD 7

Several mothers commented that the community will discourage engaged fathers, even if they wanted to participate more. Involved fathers may also be considered lazy and are ridiculed. Because men are expected to provide, they would be considered lazy if they are taking care of the child instead of working hard in the fields.

> "They [the neighbors] would discourage him" Mother, FGD 6

However, several mothers in the majority of the FGD and a few fathers stated that other mothers encouraged involved fathers if they saw some in the community. Fathers actively engaged in child care were seen by mothers are responsible and loving. Most of the key informants also confirmed these perceptions of encouragement from mothers.

> "They would say that: "this man is really responsible, he takes good care of their baby, he can do it all" Mother, FGD 1

> "They may say: "you are a wise man and you love your children, you wash clothes, etc." Father, FGD 3

In the majority of the FGD, several mothers reported that wives of involved fathers are not considered good mothers. They are often seen as lazy, rude or unable to properly take care of their children because of the gender roles around child care.

> "If they see my husband washing the dishes, they would say: "you shouldn't be doing this, why did you even get married?" Mother, FGD 2

In almost all of the FGD, mothers mentioned that women would be envious of the wives of involved fathers. Mothers consider them lucky to have a supportive husband and that they work well as a team in raising their children.

> "You are really lucky with such husband!" Mother, FGD 5

4. Discussion

Results showed strong gender role differences in child care among Malagasy parents; mothers and fathers have distinct roles. Fathers see themselves as providers, not caretakers, a perception widely held by the larger community as well. Other qualitative studies in LIMCs also reported similar findings where men's responsibility was limited to providing financial support for their family [8-10, 25, 26]. But fathers were also expected to interact with the child by teaching and playing with them. Mothers, on the other hand, were seen as the primary caregivers for the children, responsible for feeding and hygiene.

Gender role stereotypes in child care were a salient theme across the data and also one of the main barriers to fathers' involvement. Consequently, fathers participating in child care activities would be ridiculed by the community and their wives would be criticized as

irresponsible mothers unable to take care of their children. Community perceptions are important because they influence individual behaviors and actions [27]. Thus, changing these social norms could encourage fathers to be more engaged if involvement is perceived positively.

Compared to other studies from African countries [8, 9, 26], fathers in our study seem to be more involved in child care, but their involvement depends on the activity and the availability of the mothers. Fathers took part in feeding, cooking, or cleaning the child only when the mothers were unavailable, probably because of the perception that these tasks were the mothers' primary responsibility. Most of the fathers' time with children was spent on companionship and play. Similar results were reported in different settings as European, American, and Indian fathers engaged more in physical and stimulating plays than mothers [28, 29]. Father-child play is particularly important for the child's language skills and social emotional development. Fathers' playfulness has been associated with higher receptive language scores especially during play pretend activities [20]. Compared to mothers, fathers have been suggested to use more words and elaborate grammar as well as full sentences [29, 30]. Also, rough-and-tumble play between father and child was associated with socioemotional competence and self-regulation in a meta-analysis [31]. Malagasy fathers should be encouraged to talk to and play with their children regularly in addition to just holding them.

Although there is accumulating evidence of the positive results of fathers' involvement in other areas than financial support on maternal and child outcomes, challenging these perceptions may be difficult as they may be deeply rooted in the culture. Yet, increasing levels of involvement of fathers may require changing the traditional perceptions around the distinct roles of parents in child care activities. Slowly bringing awareness of the benefits and the importance of the engagement of both parents in all aspects of child care may be needed. Both parents contribute uniquely to child development because of the differences in the dynamics of their relationships with the child. Having direct interactions and activities with involved fathers and

mothers, rather than one parent alone, may expose the child to a variety of stimuli that will likely improve developmental outcomes [18]. Additionally, involving fathers in activities regarding child care, or even broadly, in unpaid work may alleviate women's workload. In our study sample, mothers were also providing for their family like the fathers, in addition to the care of children for which they are primarily responsible. As mentioned by the mothers during the focus groups, having their husbands' help will allow them to have more time to interact with their children.

Several fathers in this study mentioned that men's responsibility goes beyond provision and that they should also help their wives with household chores when their wives are busy. This finding suggests that some fathers are open to participating in other aspects of child care in addition to their perceived responsibilities for financial support and child play. In addition, several fathers were also interested and willing to be more involved.

Based on the findings, a few suggestions can be made to increase fathers' involvement in child care activities in the Vakinankaratra region. First, slowly increasing awareness of the community about the importance of fathers' involvement or child health and family life in general may change the community's perception of engaged fathers and facilitate their participation. Such strategies may be more effective using behavior change theories that address each of the attitudes and beliefs fathers and mothers in the community had towards involved fathers and their wives. Second, encouraging fathers to continue their involvement with what they currently are doing may be important as well and may facilitate their participation in other activities in childcare. Mothers play an important role in encouraging their husbands to be more involved as maternal attitudes and beliefs of fathers' roles in child care have been shown to be more predictive of fathers' involvement than the fathers' perceptions [32, 33]. Finally, gradually encouraging fathers to participate in other activities in which they expressed interest may be easier than drastically

changing the responsibilities in the household. Trainings on detailed activities fathers can be engaged in regularly may also be helpful.

The selection of the fathers is a limitation of this study as only few fathers were available, due to their work, and were willing to participate in the focus group discussions. It is possible that the participating fathers were more involved in child care activities. Fathers in our sample also received less education than the average men in Madagascar. However, this study is the first to explore fathers' involvement in child care and the potential of their involvement in promoting nutrition and developmental outcomes in the highlands of Madagascar. We also collected data from different communities using several methods to increase reliability.

5. Conclusion

In the Vakinankaratra region, traditional gender roles on child care influenced the community's perception of fathers' responsibility and are one of the barriers to their involvement. Fathers are seen as providers and mothers are considered as caregivers. When alone with their children, fathers play and teach them, or hold them when the mothers are busy. Both mothers and most of the fathers were interested in engaging fathers more in child care but another barrier was the fathers' lack of time or separation due to work. Interventions targeting both mothers and fathers and the community at large to change perceptions and attitudes towards involved fathers and their wives as well as the importance of co-parenting may increase fathers' involvement in child care in the region.

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Table V.1. Focus group questions and interview guide.

Focus group discussion questions: mothers
1. What kind of activities does your husband/partner do with the child?
2. What prevents him from being more involved in activities with the child?
3. How would you feel about getting him more involved in activities with the child?
4. How would you go about getting him more involved in activities with the child?
5. What would the neighbors/other community members think/say if he is more involved?
Focus group discussion questions: fathers
1. What are the responsibilities of the fathers regarding childcare?
2. What kind of activities do you do with your child?
3. How do you support your wife/partner in raising your children?
4. What activities would you like to do more with your child?
5. If you wanted to be more involved in childcare, what prevents you from doing so?
6. What would the other fathers think if they saw a father being involved in child care activities more than usual?
Interview guide: key informants
1. What do people think are the responsibilities of the fathers regarding child care?
2. What prevents fathers from being more involved in activities with the child?
3. What would the neighbors/community members say if they see fathers getting more involved in activities with the child?

Table V.2. Characteristics of the study population.

Variables	N	Mothers	N	Fathers
Age, mean (SD)	46	23.3 (6.3)	17	31.7 (6.1)
Occupation, %				
Doesn't work	2	4.35	0	0
Farmer	42	91.3	13	76.5
Other	2	4.35	4	23.6
Highest education level, %				
At least some primary	16	37.2	8	47.1
At least some secondary	19	44.2	4	23.5
Higher	8	18.6	5	29.4
Household size, mean (SD)	46	5.1 (2.2)		4.2 (1.5)
ANC attendance, %				
Less than 4	12	26.1	-	-
4 or more	34	73.9	-	-
Radio listening, %				
Not listening	20	43.5	5	29.4
Once or twice a week	9	19.6	3	17.6
Almost every day	17	36.9	9	52.9

Table V.3. Themes for the perceptions of fathers' responsibility in child care.

Themes	Data source	Times mentioned	Illustrative quotes
Financial and material support	Fathers FGD	12	"Yes, but even when the child is sick, you will need money so you have to be responsible. For foods and so on, for toys that the child may want because he will talk to the mother for that and she will send him to you" (Father, FGD 1)
	IDI	12	"Find money, they usually think about food, always food. And yes, that's true that when they are leaving the house, they are looking for money so that's a responsibility already. But when they found the money, they don't think much about anything else. They would just give the money to the mother and ask her to get food so the wife goes and prepares the food" (Field Monitor, IDI 7)
General care activities and spending time when mothers are busy	Fathers FGD	13	"I do that sometimes [bathing] when my wife is busy" (Father, IDI 1) "The first responsibility a father has about child care is to soothe the child if the mother is not there, to feed him so that he can grow" (Father, FGD 2)
Support for mother with chores	Fathers FGD	8	"When raising a child, most of the time, we [fathers] have to get used to it so we have to participate in taking care of the child because the mother may be busy or you may even offer to do some of the things at home" (Father, FGD 3)
	IDI	1	"Also, he [the father] should be helping the mother when she is busy" (CNA, IDI 4)
No caregiving responsibilities for fathers	IDI	4	"The father rarely takes care of the child (pause). Even when preparing the food for the child, buying it from the market, everything about the child, the mother does it. I really don't see what the fathers are doing" (Nurse, IDI 8) "Most of the time, men think that they should just provide" (CNA, IDI 5)

Child stimulation: playing and teaching	Fathers FGD	5	"You have to make sure his [the child] mind grows" (Father, FGD 2)
Console the child	Fathers FGD	5	"Making them happy when their mother is not there" (Father, FGD 3)
Supervise mothers	F	3	Supervising is then what the fathers do most of the time but the real work is for the mother only (Father, FGD 3)

FGD: Focus group discussions

IDI: In-depth interviews with key informants

CNA: Community nutrition agent

Table V.4. Themes and codes for the current fathers' involvement in child care activities.

Themes	Codes	Data source	Times mentioned	Illustrative quotes
Child home stimulation	Teaching the child	Mothers FGD	9	"He [the father] talks to him, he shows him how to play" (Mother, FGD 2)
		Fathers FGD	7	"I show him things to develop his mind because little kids cannot stay at home for long" (Father, FGD 3)
	Playing with the child	Mothers FGD	37	"For example, playing soccer or playing homemade dolls or even making the baby dance on the bed" (Mother, FGD 4)
		Fathers FGD	8	"That's how we all think about the child, so you raise him with love by playing with him" (Father, FGD 3)
General child care activities	Taking care of the child	Mothers FGD	6	"He [the father] changes his clothes" (Mother, FGD 6) "And when the baby is not well then taking care of him or taking to the health center" (Mother, FGD 4)
		Fathers FGD	5	"If they are dirty then you should take responsibility and clean them (Father, FGD 2)
	Spending time with the child	Mothers FGD	8	"They [fathers] can take a walk with the children, for example looking for things the children can play with" (Mother, FGD 7)
		Fathers FGD	2	"For me, I take him [the child] around" (Father, FGD 3)
	Holding the child	Mothers FGD	6	"When I am washing the clothes, I will make him hold the baby" (Mother, FGD 7)
		Fathers FGD	7	"For me too in the evening, I hold the baby, that's what I do" (Father, FGD 1)
Food preparation and feeding	Cooking and feeding	Mothers FGD	10	"When the food is ready, they can feed the baby" (Mother, FGD 4)

		Fathers FGD	11	"She goes every Thursday to deliver potatoes to go to Antananarivo, so she doesn't bring the children. Then I have to stay at home with my two boys. So, I prepare their foods and I feed them" (Father, FGD 3) "For example, when the mother is busy, I can prepare the food and feed him" (Father, IDI 1)
Support mothers	Help with household chores	Fathers FGD	10	"The way I help her, for me when it's the evening like this, there are less things to do, so I go and get groceries and then I come back" (Father, FGD 1)
	Work on agriculture	Fathers FGD	1	"For example, if we plant, we do them together, maybe the women will plant or put the fertilizer, but we sow together, we plant greens together. Also, for example, when we weed the corn, when we have to dig, we do them together, some will put the fertilizer, some will sow" (Father, FGD 3)

FGD: Focus group discussions

IDI: In-depth interviews with key informants

CNA: Community nutrition agent

Table V.5. Themes and codes for the barriers to fathers' involvement in child care activities.

Themes	Codes	Data source	Times mentioned	Illustrative quotes
Fathers' work and related factors	Limited time because of work	Mothers FGD	23	"He [the father] is busy working all the time so he can't take care of the baby" (Mother, FGD 1)
	Limited time and unavailable because of work	Fathers FGD	11	"The main problem as discussed earlier, the main problem for us is that we are not always home even if we wanted to be more involved" (Father, FGD 2)
	Separation and distance	Fathers FGD	9	"For example, when he is working in Ambatondrazaka or Maevatanana (bigger towns in another region), he is gone for months, one or more, so he can't be with the baby" (Mother, FGD 2)
	Tired from work	Mothers FGD	8	"They [fathers] are tired from work and they don't want to do anything anymore" (Mother, FGD 7)
		Fathers FGD	2	"For me when I am tired from the fields" (Father, FGD 1)
		IDI	12	"When the fathers are tired from work, they don't care about their children" (CNA, IDI 2)
Traditional gender roles on child care	Mothers are the primary caregiver	Mothers FGD	16	"He [the father] may do things when you [the mother] are not around. He will take care of the baby if you are not around for half a day or so. But if both of us are there and if the child is vomiting, he will ask me to take care of it" (Mother, FGD 1)
		IDI	6	"And some [fathers] would say that the women are there for taking care of the children" (Nurse, IDI 8)
	Fathers are providers, not caregivers	Fathers FGD	1	"For us men we have to provide so we don't have to be so close to the child, not more than their mothers" (Father, FGD 1)

Lack of willingness from the fathers	Mothers FGD	8	"He [father] even says sometimes that I don't know how to take care of babies…but when I am not around he knows how to take care of them but it's only when I am around that he doesn't want to do it" (Mother, FGD 4)
	IDI	7	"It's the willingness that is lacking, they just don't want to" (Field Monitor, IDI 7)
Fathers not prepared	Mothers FGD	17	"They [fathers] can't understand all of the things you have to do to take care of a child. For them, when they are clothed and fed then that's it. They don't know how to take care of the other things" (Mother, FGD 3)
	IDI	5	"It's just not their habit, they are not used to do it. They haven't been doing it because the women have always been doing it" (CNA, IDI 5)
Fathers are irritable and worried	Mothers FGD	3	"Sometimes they [fathers] are irritable" (Mother, FGD 3) "Also, sometimes, there is something that worries him [father] so he won't touch the baby" (Mother, FGD 3)
	Fathers FGD	1	"And if there is something else that worries me, then it is hard to take the baby so I go away for a bit" (Father, FGD 1)

FGD: Focus group discussions

IDI: In-depth interviews with key informants

CNA: Community nutrition agent

Table V.6. Themes and codes for the community perceptions of involved fathers and their wives.

Themes	Codes	Data source	Times mentioned	Illustrative quotes
Traditional gender roles on child care: caregiving is mothers' job		Mothers FGD	9	"They [fathers] will say that those are the women's responsibility, not theirs" (Mother, FGD 3)
		Fathers FGD	4	"They [the community] will ask if there is no woman in the house that you would have to do that [taking care of the child]" (Father, FGD 1)
		IDI	6	"Some [people] would just say that why would they care about that, that the father should not do all of those things [child care activities], they would ask what does the mother do" (CNA, IDI 2)
Perceptions of involved fathers	Involved fathers are controlled by their wives	Mothers FGD	6	"Because they are men, they won't let women undermine them. His friends will ask him why does he wash the clothes when the wife is there" (Mother, FGD 4) "Your wife is controlling you, she makes you do chores", that's what they would say" (Mother, FGD 6)
		Fathers FGD	1	"They would say: "the man doesn't stand for himself, the woman has overpowered him, etc.", according to the saying" (Father, IDI 1)
		IDI	2	"They would say that that man is being controlled by the wife, that the wife has him under her control, and that he is doing whatever she says" (CNA, IDI 2)
	Involved men are weak	Mothers FGD	4	"They [other fathers] would say that he is a weak man" (Father, FGD 3)

	Involved fathers are discouraged by the community	Mothers FGD	3	"Nobody will ever encourage a man to wash clothes (laughter)" (Mother, FGD 4)
	Involved men are good fathers	Mothers FGD	16	"They will say: "Look at this man, he is doing this and that, he really takes care of his child, he is taking his responsibilities towards the child, not like you [her own husband]" (Mother, FGD 5)
		Fathers FGD	5	"For me, I think the mothers will encourage because they love their children, it's in them, men can love their children but their mothers carried them for 9 months so whenever they see other people's children being taken good care of, they would say that those children are lucky because their dad is very responsible doing those things" (Father, FGD 1)
		IDI	5	"They would be happy, they would say that the father really loves his children, they would be happy" (CNA, IDI 3)
	Involved fathers are lazy and laughable	IDI	2	"They would say that that man is lazy, which happens a lot actually. They would say that man doesn't want to work so he is just taking care of the child" (CNA, IDI 5)
		Mothers FGD	1	"Men don't wash clothes. You can't see men grinding paddy, they will be embarrassed even if they want to do things because the other people will make fun of them so they won't do it. That's most of the men in the country side" (Mother, FGD 4)

Attitudes towards wives of involved fathers	Wives of involved fathers are not good mothers and wives	Mothers FGD	18	"Yes, lazy. They will say that she is not like other people's wives, they can do it all but not her, she has to rely on the husband" (Mother, FGD 5)
		Fathers FGD	1	"They will say that my wife is not doing anything at home because I am doing all the work" (Father, FGD 1)
		IDI	1	"The wife [of the involved father] is not polite and she doesn't know what she is supposed to do. Some mothers can say that" (CNA, IDI 3)
	Neighbors are envious of the wives of engaged men	Mothers FGD	18	"They would envy the wife [of the involved father]: "if only my husband was like that" (Mother, FGD 7)
		IDI	2	"They would envy her [wife of the involved father], they would tell each other their problems and say if only their husbands were more like that" (CNA, IDI 5)

FGD: Focus group discussions

IDI: In-depth interviews with key informants

CNA: Community nutrition agent

CHAPTER VI

SOCIODEMOGRAPHIC PREDICTORS OF CHILD GROWTH IN THE VAKINANKARATRA REGION OF MADAGASCAR

Abstract

Despite the very high burden of child undernutrition in the Vakinankaratra region of Madagascar, there are limited studies evaluating the factors associated with child growth. The purpose of this study was to identify the region-specific sociodemographic predictors of child growth in children under two years. Sociodemographic information regarding the child and the household were collected using surveys of mothers. Child length-for-age (LAZ), weight-for-age (WAZ), and weight-for-length (WLZ) according to the 2006 WHO standards were used to assess child growth as dependent variable in the analyses. Independent variables were grouped into three domains: immediate (child), underlying (maternal and household), and community (commune of residence). Linear regression models were conducted for each domain for each growth indicator to select the set of predictors to be included in the final models using the AIC and R^2 criteria. Child stunting rate was 69.4%, underweight prevalence was 23.4% and 3.2% of the children were wasted. Only higher birthweight predicted an increase in all three indicators. In the final models, increased child age was associated with lower LAZ ($ß = -0.21$, $p < 0.01$) and WAZ ($ß = -0.13$, $p < 0.05$).

Higher maternal height predicted increased LAZ (ß = 0.17, $p < 0.01$) and WAZ (ß = 0.16, $p < 0.01$), while larger household size was associated with decreased LAZ (ß = -0.10, $p < 0.05$) and WAZ (ß = -0.16, $p < 0.01$). Use of iodized salt predicted higher WAZ (ß = 0.12, $p < 0.05$) while higher wealth index was associated with increased WLZ (ß = 0.13, $p < 0.05$). Communes of residence were also predictors of LAZ and WLZ in the final models. Efforts to reduce child undernutrition in the region need to consider these identified predictors of child growth.

1. Introduction

Child undernutrition remains a serious public health issue, especially in sub-Saharan Africa, where the total number of stunted children increased by 8.5 million over the past two decades [1]. In addition to increased risks of infectious diseases and death [2] and poor development [3, 4], child undernutrition also can have negative long-term effects. Undernourished children are likely to grow up to be less productive adults and earn lower wages [2, 5-7], and their offspring will have increased risk of undernutrition [8]. Because these consequences at both the individual and community level could be carried forward to the next generation, global efforts have focused on reducing child undernutrition. The World Health Assembly (WHA) has the ambitious target of reducing stunting rates by 40% and maintaining wasting prevalence less than 5% by 2025 [9, 10].

Despite the implementation of a national community nutrition program since 1999, Madagascar is still one of the countries with the highest burden of undernutrition. The latest Multiple Indicator Cluster Survey (MICS) in 2018 reported that 42% of children under the age of five were stunted, 26% were underweight, and 6% were wasted [11]. Undernutrition rates vary notably across regions with the Vakinankaratra region having the highest stunting (60%) and underweight (40%) prevalence.

To effectively reduce these high undernutrition rates in the region, evidence-based nutrition interventions and policies will need to be implemented [12, 13]. Also, such interventions should be tailored to the local context to ensure effectiveness and sustainability. However, only limited studies have evaluated the immediate, underlying, and community factors of child undernutrition in the Vakinakaratra region specifically. In addition, fathers' involvement in child care continues to receive attention because of its potential to improve maternal and child health [14-16]. Data on the influence on child growth of fathers' participation in child care-related activities in Madagascar are lacking. Thus, the purpose of this study was to identify the

sociodemographic factors, including fathers' involvement, associated with child growth in the Vakinankaratra region. Results of this study can be used to design context-specific interventions and to adjust current and future policies or programs to prevent child undernutrition in the region.

2. Methods

Study setting and participants

This study was conducted in two rural districts of the Vakinankaratra region: Antanifotsy and Antsirabe II. Mothers having infants aged 6 – 23 months living with their husband or partner were eligible for the study. A total of 391 mother-child dyads were enrolled based on the regional stunting rate of 55% [17] and a margin of error of 0.05. A multiple stage cluster sampling at the district, commune, and fokontany (smallest administrative unit) levels was used to select participants. Communes and fokontanys covered by the national community nutrition program (*Programme National de Nutrition Communautaire* or PNNC) were included in the randomization process. Communes (8) with poor road conditions and inaccessible by car were replaced by the next commune in the randomization list. Similarly, fokontanys (10) with difficult access (i.e. more than two hours walk from the main town) were eliminated and replaced. In total, 42 fokontanys (out of 84) were included in the study. Within each fokontany, an average of eight eligible mothers per fokontany were randomly selected based on the latest local census.

Questionnaire and anthropometric measurements

Child length was measured to the nearest 0.1 cm using a locally constructed wooden length board. Measurements were done in duplicate and the average length was recorded. A hanging scale (SECA) was used to measure child weight. Using the 2006 WHO growth standards [18], child length and weight were converted to length-for-age (LAZ), weight-for-age (WAZ), and weight-for-length (WLZ) z-scores with WHO Anthro v.3.2.2. LAZ < -2 indicated stunting,

WAZ < -2 indicated underweight, and children with WLZ < -2 were wasted. Maternal height was measured against a plastic tape attached to a wall.

A questionnaire adapted from the Demographic and Health Surveys [19] was used to collect sociodemographic information related to the child, the mother, and the household. A wealth index was constructed based on household assets using principal component analysis [20]. The Household Food Insecurity Access Scale (HFIAS) was used to assess food security [21]. Fathers' involvement was assessed using a questionnaire adapted from Abate and Belachew [16]. The questionnaire was pre-tested and clarified before data collection.

Conceptual framework

A conceptual framework based on the UNICEF model on the causes of child undernutrition [2, 9, 22] was developed to guide the analyses (figure VI.1). Variables were grouped into immediate, underlying, and community factors. Immediate causes included factors directly related to the child such as age, sex, morbidity in the last two weeks, and deworming in the past six months. Underlying causes include maternal and household factors such as maternal education, health seeking behaviors, fathers' involvement, and household wealth index. The different communes of residence were considered community factors.

Statistical analyses

For descriptive statistics, means and frequency distribution of variables were compiled. Extreme z-scores values (LAZ < -6, LAZ > 6) were excluded from the analyses [18]. Continuous dependent variables (LAZ, WAZ, and WLZ) were checked for normality using their histogram distributions. Only LAZ was not normally distributed and was transformed using the logarithm function after adding a constant value of eight. A series of linear regression models were used to

identify individually the predictors of LAZ, WAZ, and WLZ. For each domain and each indicator, multiple regression models were performed and the model with the highest R^2 and lowest Alaike Information Criterion (AIC) was retained. Identified variables for each domain were then used to build the final model for each indicator. Ordinal and nominal categorical variables were dummy coded before analysis. Multicollinearity was checked using the Variance Inflation Factor (VIF) and all values were within acceptable ranges (< 4).

3. Results

Characteristics of the study population

Mean child age was 14.1 months and half of the children were male (table VI.1). More than half of the children were coughing within the prior two weeks and more than one third had fever. Only 4.8% of the mothers had not received at least primary education; more than three-fourths of the mothers were farmers. Also, 35% of the mothers had given birth before the age of 19, and the majority did not listen to the radio the week before the survey. Only three households used an unimproved source of drinking water (river and/or lake) and 2.3% did not have sanitation facilities. However, two-thirds of the households shared their latrines with other families. Almost all of households (93.3%) were food insecure as assessed with the HFIAS. All of the households were smallholder farmers; an average agricultural land size was 44 m^2 with a median of 27 m^2, but the majority (73.7%) owned smaller than the average. Child undernutrition rates were very high: 69.4% of the children were stunted, 23.4% were underweight, and 3.2% were wasted.

Predictors of LAZ

Immediate factors associated with LAZ included age, sex, and birthweight (table VI.2). Increased age was significantly associated with lower LAZ (ß = -0.21, $p < 0.01$), while being

female (ß = 0.18, p < 0.01) and having higher birthweight (ß = 0.11, p < 0.05) were associated with higher LAZ. Age, sex and birthweight remained significant in the final model.

Higher maternal height in cm predicted higher LAZ (ß = 0.17, p < 0.01). Children whose mothers listened to the radio once or twice in the past week had higher LAZ (ß = 0.15, p < 0.01) in the final model compared to the children whose mothers did not listen to the radio at all. Increased attendance at antenatal care sessions was significantly associated with higher LAZ (ß = 0.12, p < 0.05). Larger household size predicted lower LAZ (ß = -0.10, p < 0.05). Fathers' involvement was not significantly associated with LAZ.

For the community factors, Ibity was chosen as a reference because it was the commune farthest from the main city of the region. Compared to children in the Ibity commune, children living in the communes of Ambohimandroso, Ambohibary, Ambohidranandriana, and Andranomanelatra had significantly lower LAZ.

Predictors of WAZ

For the immediate factors, only age and birthweight remained significant predictors for WAZ in the final model (table VI.3). Older children had lower WAZ (ß = -0.13, p < 0.05) and higher birthweight was significantly associated with increased WAZ (ß = 0.18, p < 0.01). Higher maternal height (ß = 0.16, p < 0.05) and use of iodized salt both predicted increased WAZ (ß = 0.12, p < 0.05). Similar to LAZ, increased household size was significantly associated with lower WAZ (ß = -0.16, p < 0.01). None of the fathers' involvement variables was significantly associated with WAZ.

Predictors of WLZ

Only birthweight among the immediate factors remained significant in the final model (table VI.4). Higher birthweight was associated with increased WLZ (ß = 0.13, $p < 0.01$). None of the maternal and fathers' involvement variables were significantly associated with WLZ. Higher wealth index predicted increased WLZ (ß = 0.13, $p < 0.05$). Children whose mothers do not fetch the drinking water had significantly lower WLZ (ß = -0.12, $p < 0.05$). And compared to children from the Ibity commune, children from the Mandrosohasina had significantly higher WLZ (ß = 0.19, $p < 0.05$).

4. Discussion

More than two thirds of the children under two in the Vakinankaratra region were stunted, and underweight prevalence was also high (23.4%). Both of these values are above what the WHO recognizes as public health concerns emphasizing the alarming situation in the region [23].

Growing older was a risk factor for both stunting and underweight. Global growth trajectory showed that LAZ and WAZ decrease dramatically during the first two years in low- and middle-income countries [24, 25]. The slope of the decline is particularly steep after the first six months emphasizing the critical role of the complementary feeding period (6 – 23 months) for child growth. Similar to the findings from other countries in sub-Saharan African, males were more likely to be stunted than females [26]. The reasons for sex differences in risk of stunting are not clearly understood but comparison of optimal growth curves showed that males are consistently taller than females [27]. Thus, given the same feeding patterns, males may be more likely to be undernourished. Although not captured in this study, another possible explanation is the difference in breastfeeding and complementary feeding practices depending on the infant's

sex. In Senegal, boys were introduced to complementary foods much earlier than girls, many before they reached 6 months, which could increase their risk of stunting [28].

Higher birthweight was a predictor of better child growth regardless of the indicator. Low birthweight is a known risk factor for undernutrition as reported in the meta-analysis of 19 birth cohorts from 14 LMICs countries [29]. The fact that undernutrition begins *in utero* and that birthweight was a significant predictor of growth suggests the importance of maternal nutrition during pregnancy in our sample. A qualitative study in another region of Madagascar's highlands reported that pregnant and lactating women ate mostly rice and green leafy vegetables with limited protein sources or fruits [30]. Additionally, size at birth is influenced by preconceptual maternal nutritional status as well as weight gain during pregnancy [31]. In Vietnam, mothers with lower pre-pregnancy weight were more likely to give birth to infants with low birthweight [32]. Thus, because of the high rate of low birthweight (23.5%), efforts to improve maternal nutritional status before conception and during pregnancy to prevent low birthweight may help reduce child undernutrition in the Vakinankaratra region.

Maternal height was also a strong predictor of child length and child weight, similar to the findings from a multi-country analysis where children born of shorter mothers had higher risks of stunting and underweight [33]. The contribution of maternal height to child growth may be a combination both of genetic factors [34] and the environmental conditions such as overall poverty and food insecurity of the households [12]. Analyses of birth cohort data from various LMICs showed that the effects of maternal undernutrition on child growth faltering are likely to carry over to the next two generations [7]. Consequently, breaking the intergenerational cycle of malnutrition is urgently needed in areas with high burdens of infant and child undernutrition such as the Vakinankaratra region.

Increased attendance at antenatal care sessions was significantly associated only with increased child length. Having at least one antenatal care visit has been associated with lower percentages of low birthweight, stunting, and underweight in a pooled analysis of 193 sets of Demographic and Health Survey data from 69 LMICS [35]. Antenatal care provides an opportunity to prevent negative birth outcomes, including low birthweight and small for gestational age, which are strong predictors of child undernutrition [12, 29]. The WHO recommends at least eight antenatal care visits for better pregnancy outcomes including reduced maternal and neonatal deaths [36]. Nutrition recommendations during pregnancy include counselling by health care providers regarding healthy eating and physical activity as well as daily iron and folic acid supplementation. In Madagascar, antenatal care services including provision of supplements and vaccines are free of cost but they are not always available [37]. Also, a lack of qualified personnel, especially in remote areas, as well as poor infrastructure have been reported in health care centers [37]. Improving the antenatal care services at the local health care units may be required to promote maternal and newborn health as well as subsequent child growth.

Larger household size was a predictor of both low LAZ and WAZ, in accordance with a previous study from Madagascar [17] and other studies from LMIC countries [38, 39]. Large family size may limit resources as well as time for child care in households with food insecurity.

Children living in households using iodized salt weighed more. Iodine plays a key role in growth and development through the action of the thyroid hormones, thus iodine deficiency may lead to impaired growth [40]. Also, use of iodized salt may reflect higher household wealth. Iodine surveys from Madagascar [41] and other LMICs [42] consistently showed that wealthier households had more access to and ability to buy iodized salt compared to poorer families. Higher wealth may also mean access to more nutritious foods. In our results, higher household wealth index was significantly associated with increased WLZ only.

There is no clear explanation of the finding that children whose mothers were not in charge of fetching drinking water had lower WLZ. If not the mother, older children and other family members such as the mothers' younger sister were fetching the water, which may suggest larger family size, which is associated with slower growth. The other household water and sanitation conditions were not significantly associated with any of the growth indicators. However, most households in our sample had relatively good water and sanitation conditions. Almost all of the households used improved drinking water sources (99.2%) and only 9.1% spent more than 30 minutes to fetch water. Also, availability of latrine was almost universal (97.7%), although a third of the households shared latrines with other families. A previous study from Madagascar reported sharing latrines is a risk factor for stunting particularly in 24 to 59 month old children [17]. Strategies to encourage building and use of latrines for each household are needed to improve the sanitation and hygiene conditions of the population in Vakinankaratra.

Commune of residence was a predictor of stunting and wasting, which could be explained by multiple factors. Due to their remote locations, some fokontanys had limited access to health care and information. A recent analysis of growth patterns in 64 LMICs country from 1993 to 2015 showed that child length as z-scores declined for the entire population, not only for vulnerable children, during the first three years [43]. These results suggest that improving community level conditions are also key in promoting child growth as all children are exposed to the same factors.

Also, although no formal data collection was conducted to assess levels of commitment of local health workers, we observed differences across communities from field work activities and personal communications with CNAs. Local CNAs from more remote areas, such as Ibity, were more invested in the routine activities (growth monitoring and nutrition education sessions) than those from sites closer to the urban areas, such as Ambohimandroso or Andranomanelatra. "Newer" CNAs (selected during the second phase of the national community nutrition program)

have been reported to have lower motivation compared to their "older" counterparts, who have held their positions since the first phase of the program in 1999 [44]. All of the CNAs in the Ibity commune were first elected in 1999 and have been re-elected during the second phase as well. Program sites implemented since the first phase had also been reported to sustain the reductions of child underweight until 2011.

Fathers' involvement in child care as assessed in this study was not significantly associated with any of the child growth indicators. This is, to our knowledge, the first study to investigate the influence of male engagement in child care on child nutrition outcomes. Given the recent interest in fathers' involvement in child care and the potential of fathers in promoting maternal and child health in LMICs, more comprehensive and validated tools are warranted in countries such as Madagascar. Because of its highly contextual nature [45], a variety of assessments using validated tools may be necessary for more accurate evaluation of fathers' involvement.

In the Vakinankaratra region, sociodemographic variables explained almost a quarter (24%) of the variance in child length, but only explained 18% of variance in child weight and 12% in weight-for-length. The greater influence of sociodemographic variables on child length emphasize the cumulative influence of the child's environment on linear growth and the acute nature of underweight and wasting. Our results showed that stunting, underweight, and wasting had several different predictors. Thus, for increased effectiveness, nutrition intervention components need to be different according to the targeted nutrition outcome of interest.

The cross-sectional design of this study does not allow for causal inference. Also, only communities covered by the national community nutrition program were included in this study, which may limit the generalization of our findings to the whole Vakinankaratra region. Another limitation is that data were collected through surveys; thus, the possibility of social desirability

and recall biases should be acknowledged. However, to the best of our knowledge, this study is the first to identify region-specific sociodemographic predictors of child growth in Vakinankaratra. Also, a wide range of potential factors were tested at the child, maternal, and household, and community levels.

5. Conclusion

The child undernutrition situation in the Vakinankaratra region requires immediate attention as more than two thirds of the children under two were stunted and 23.4% were underweight. Sociodemographic predictors of child undernutrition were identified at the individual, household, and community level. Addressing these determinants at more than one of the three levels need be considered in efforts to reduce the very high child undernutrition rates in the Vakinankaratra region.

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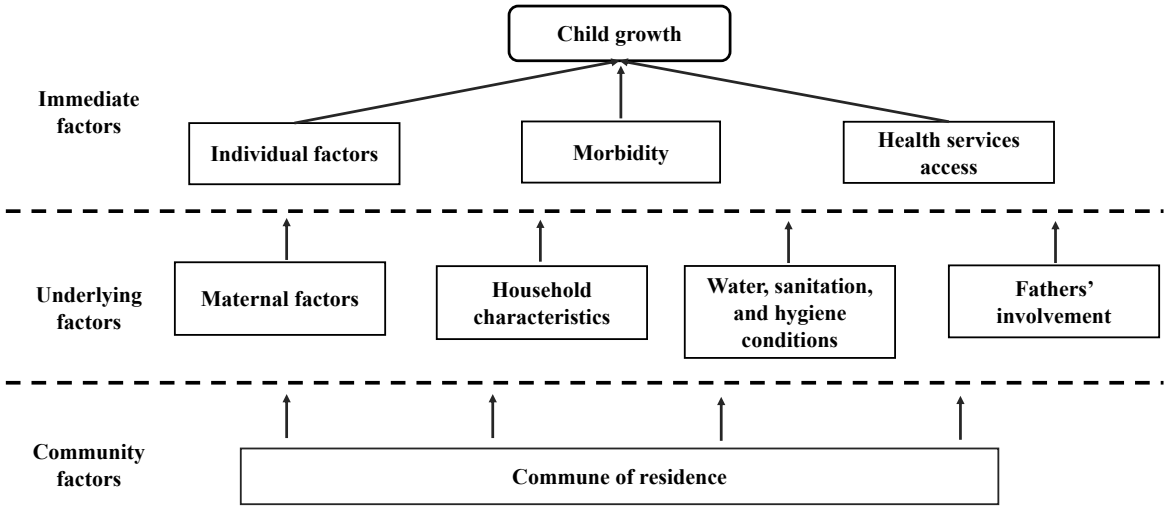

Figure VI. 1. Conceptual framework for the sociodemographic factors influencing child growth. Adapted from Black *et al.* [12]; WHO, UNICEF, WFP [9]; and UNICEF [22].

Table VI.1. Characteristics of the study sample.

Variables	N	Frequency (%) or mean (SD)
Child characteristics		
Child age, months	391	14.1 (5.2)
Child sex		
Male	197	50.4
Female	194	49.6
Diarrhea, %		
No	279	71.9
Yes, last 2 weeks	108	27.8
Missing	4	
Cough		
No	161	41.3
Yes, last 2 weeks	229	58.7
Missing	1	
Fever		
No	249	63.7
Yes, last 2 weeks	142	36.3
Maternal characteristics		
Maternal age, years	391	27.4 (6.8)
Maternal education		
No education	18	4.6
At least some primary	204	52.6
At least some secondary	118	30.4
Higher	48	12.4
Missing	3	
Maternal occupation		
Doesn't work/housewife	31	8.0
Farmer	308	78.8
Part-time work	3	0.8
Other	49	12.5
Maternal age at first birth		
< 19 years	137	35
≥ 19 years	254	65
Listen to radio		
Not at all	217	56.1
Once or twice	45	11.6
Almost every day	125	32.3
Missing	4	
Antenatal care attendance		
Less than 4	113	28.9
4 or more	278	71.1

Household factors		
Water source		
River and lakes	3	0.8
Wells	145	37.1
Spring water	151	38.6
Tube wells	4	1.0
Tap water	88	22.5
Sanitation facilities		
Forest/bush	8	2.0
River/lakes	1	0.3
Latrines	382	97.7
Shared latrines		
No	129	33.4
Yes	257	66.6
Missing	5	
Wealth index		
Lowest	123	33.4
Middle	122	33.1
Highest	123	33.4
Missing	23	
Household size	384	4.9 (1.9)
Food insecurity status		
Food secure	26	6.7
Mildly food insecure	15	3.9
Moderately food insecure	130	33.4
Severely food insecure	218	56.0
Missing	2	
Land size[1]		
< 44 m^2	288	73.7
≥ 44 m^2	103	26.3
Undernutrition prevalence		
Stunting	268/385	69.4
Mean LAZ (SD)		-2.4 (1.4)
Underweight	88/376	23.4
Mean WAZ (SD)		-1.2 (1.1)
Wasting	12/376	3.19
Mean WLZ (SD)		0.1 (1.2)

LAZ: Length-for-age z-score

WAZ: Weight-for-age z-score

WLZ: Weight-for-length z-score

[1]44.05 m^2 is the average land size in the study sample, median is 27 m^2

Table VI.2. Predictors of length-for-age z-scores (LAZ) in children aged 6 – 23 months in the Vakinankaratra region, Madagascar (n = 383), $R^2 = 0.24$.

Predictors	ß	p-value
Immediate factors		
Child age (months)	-0.21	0.0057
Child sex (ref. male)	0.18	0.0033
Birthweight (g)	0.11	0.0387
Coughing the past two weeks	-0.10	0.0546
Underlying factors		
Maternal height (cm)	0.17	0.0025
Listened to radio (ref. did not listen at all)		
Once or twice a week	0.15	0.0084
Every day	0.01	0.8871
Number of antenatal care sessions attended	0.12	0.0151
Number of postnatal care sessions attended	0.11	0.0452
Household size	-0.10	0.0281
Communes[1]		
Antanifotsy	-0.06	0.3786
Ampitatafika	-0.02	0.8075
Ambohimandroso	-0.23	0.0001
Ambohibary	-0.23	<.0001
Ambohidranandriana	-0.14	0.0205
Andranomanelatra	-0.28	<.0001
Antanimandry	-0.11	0.1648
Mandrosohasina	-0.12	0.1413

Results are expressed in standardized ß coefficients from the final model

[1]Ibity commune was the reference

Table VI.3. Predictors of weight-for-age z-scores (WAZ) in children aged 6 – 23 months in the Vakinankaratra region, Madagascar (n = 376), $R^2 = 0.19$.

Predictors	ß	p-value
Immediate factors		
Child age (months)	-0.13	0.0251
Child sex (ref. male)	0.11	0.0529
Birthweight (g)	0.18	0.0039
Coughing the past two weeks	-0.06	0.2672
Underlying factors		
Maternal height (cm)	0.16	0.0131
Antenatal care sessions attended	0.10	0.0752
Postnatal care sessions attended	-0.08	0.2097
Place of delivery (ref. home)	0.05	0.3024
Household size	-0.16	0.0032
Iodized salt (ref. not using iodized salt)	0.12	0.0495
Wealth index (ref. poorest)	0.13	0.0564
Shared latrines (ref. not sharing)	-0.12	0.0659

Results are expressed in standardized ß coefficients from the final model

Table VI.4. Predictors of weight-for-length z-scores (WLZ) in 6 – 23 months children in the Vakinankaratra region, Madagascar (n = 376), $R^2 = 0.12$.

Predictors	ß	p-value
Immediate factors		
Child age (months)	-0.12	0.1212
Child sex (ref. male)	-0.01	0.714
Birthweight (g)	0.13	0.007
Received deworming in the past 6 months	-0.12	0.1179
Underlying factors		
Wealth index (ref. poorest)	0.13	0.0042
Person fetching the water (ref. mother)	-0.12	0.0331
Communes[1]		
Antanifotsy	0.08	0.4947
Ampitatafika	0.06	0.3835
Ambohimandroso	0.10	0.2639
Ambohibary	0.11	0.1005
Ambohidranandriana	0.07	0.3808
Andranomanelatra	0.08	0.4252
Antanimandry	0.11	0.274
Mandrosohasina	0.19	0.0185

Results are expressed in standardized ß coefficients from the final model

[1]Ibity commune was the reference

CHAPTER VII

UNDERNUTRITION. FEEDING PRACTICES, AND CHILD DEVELOPMENT IN THE VAKINANKARATRA REGION OF MADAGASCAR

Abstract

The Vakinankaratra region of Madagascar has a high burden of child undernutrition, which is a strong risk factor of poor child development. However, there are limited studies evaluating the relations between development deficits and child nutrition outcomes in the region. The purpose of this study was to assess the development of children aged 11 to 13 months and parental home stimulation practices and to examine the differences in development across nutritional status and feeding practices in the Vakinankaratra region. Cognitive (n = 36), language (n = 36), motor (n = 36), and socioemotional (n = 76) development were assessed using the Bayley's Scale for Infant and Toddler Development III. Household stimulation environment was evaluated using the Family Care Indicators subscales. The WHO Infant and Young Child Feeding indicators were used to assess complementary feeding practices. Stunting (length-for-age z-score < -2) and underweight (weight-for-age z-score < -2) were determined using the 2006 WHO growth standards. Very high stunting rates (> 69%) and suboptimal complementary feeding practices were observed in this subsample.

Almost all mothers reported that parent-child interaction with talk and play were very important. Most of the mothers used household objects (75%) and materials from outside the house (71%) as children's toys. Common adult-infant interactions were siting and talking during meals as well as play. Composite cognitive [mean (SD): 60 (10.3)], motor [61.9 (13.4)], language [62 (13.2)], and socioemotional [85.1 (17.9]) scores were low. There were no statistical differences in child development scores based on nutritional status. Fine motor, cognitive, receptive, and expressive language scores were correlated [$0.4 < r < 0.7$, $p < 0.05$]. The very high stunting rates and very low performance on cognitive, motor, language, and socioemotional development tests of children in the Vakinankaratra region require urgent attention.

1. Introduction

The critical window of opportunity for infants and young children during the first two years of life was recognized after the large body of evidence showing that several of the biological processes required for appropriate growth and development occur during that period [1, 2]. Children having poor child development are less likely to reach their full potential and will be less productive as adults [3]. Inadequate development during childhood has been associated with fewer years of schooling and lower academic achievements, ultimately leading to lower earnings in adulthood [3]. Child development is heavily influenced by genetics, environmental, and nutritional factors starting as early as conception [4]. Nutrient adequacy during infancy is critical for optimal brain formation. Deficiencies in protein, polyunsaturated fatty acids and certain micronutrients such as iron, iodine, folate, and zinc have been shown to impact negatively child development [2, 5-8]. Additionally, linear growth faltering has been identified as a strong risk factor for poor development because of its consistent association with developmental delays [3, 9-11].

Two-thirds of the estimated 250 million children affected by suboptimal development live in sub-Saharan Africa [12]. In Madagascar, two of the strongest risk factors for impaired development, child stunting and extreme poverty [3, 13], are widespread. Consequently, delayed development has been reported for Malagasy children [14, 15]. There is also evidence of disparities in child developmental outcomes across socioeconomic status and across regions of residence [14, 16]. The Vakinankaratra region has the highest child stunting rates in Madagascar (60%) [16], making the majority of the children at risk of not reaching their full potential. However, there are limited data on the interplay between nutrition and development outcomes in this region. Thus, the purpose of this study was to assess the development of children younger than 2 years and stimulation practices in their homes, and to examine the differences across nutritional status and feeding practices.

2. Methods

This study was conducted in a subsample of 11 to 13 months young children from cross-sectional study investigating the possible causes of the very high stunting rates in the Vakinankaratra region.

Child development assessment

The Bayley's Scales of Infant and Toddler Development (Bayley-III) [17] was used to assess cognitive, language, motor, and socioemotional development. Some illustrations in the picture book were replaced with more culturally appropriate pictures. For example, an adult vacuuming was replaced by a mother sweeping the ground; also pictures of Caucasian and Asian children were replaced with pictures of Malagasy children. The assessment tools were pre-tested on two young children aged 12 and 15 months before data collection. Cognitive, language, and motor tests were conducted with 36 young children aged 11 – 13 months at the local community nutrition sites. Tests were started with tasks designated for the preceding age group, 9 – ≤ 11 months, and children had to have three consecutive successes to continue. Ceiling was reached when children did not succeed on five consecutive items.

Socioemotional development was assessed using a questionnaire administered to the mothers for all 76 young children aged 11 – 13 months in the original sample. Questions were translated in Malagasy, then reviewed by two mothers and two fathers of children younger than two years who were also native speakers. Probing questions were used by the interviewers as necessary to help the mothers better understand the concepts being asked. Raw, scaled, and composite scores for each subtest of child development were calculated and reported. Scaled and composite scores are age-adjusted allowing for similar age comparisons. The Family Care Indicators subscales [18, 19] were used to assess levels of home stimulation. Information

regarding play activities, varieties of play materials, and sources of play materials were collected by questionnaire from mothers.

Anthropometric measurements and child feeding practices

Child length was measured to the nearest 0.1 cm using a locally constructed wooden length board. Weight was measured using a hanging scale (SECA). Length and weight were converted into z-scores according to the 2006 WHO Growth Standards [20] using the WHO Anthro software. Young children with length-for-age z-scores < -2 were considered stunted, weight-for-age z-scores < -2 underweight, and weight-for-length z-scores < -2 wasted.

The WHO Infant and Young Child Feeding (IYCF) indicators were used to assess feeding practices. Minimum dietary diversity (MDD), minimum meal frequency (MMF), minimum acceptable diet (MAD), and consumption of animal-source foods were assessed using a questionnaire based on maternal recall of the foods given to the child the previous day. Foods were classified into seven groups: grains, roots and tubers, legumes and nuts, dairy products, eggs, flesh foods (meat, fish, poultry, organ meat), vitamin A-rich fruits and vegetables, and other fruits and vegetables. MDD was achieved if the child was given four or more food groups. MMF was achieved when the child was fed complementary foods three times. Children achieved MAD if they had both MDD and MMF.

Statistical analyses

Descriptive statistics were used to report the characteristics of the study population as well as the child development scores. Student's t-test was used to assess significant differences in scores of undernourished and children with optimal growth and to compare the scores between children who had optimal feeding practices and those who did not. Pearson's correlation was used

to determine correlation coefficients between developmental domains. Analyses were conducted with R (R Core Team, Vienna, Austria) and statistical significance was set at $p < 0.05$.

3. Results

Children tested for socioemotional development (n = 76) and those tested on cognitive, language, and motor development (n = 36) had similar characteristics (table VII.1). Essentially, half of the children were females, and low birthweight was > 20% in both subgroups. Mean maternal age was similar in subgroups and almost all mothers (97%) had at least some primary education. Mean (SD) household size was 4.3 (1.3) and almost half of the households did not use iodized salt.

Suboptimal complementary feeding practices were prevalent (table VII.2). Only 38% of the children achieved the minimum dietary diversity, 34 % received the minimum acceptable diet, and 14% consumed animal source foods. Results were similar in the cognitive, language, and motor development subgroup. Proportion of children achieving the minimum meal frequency was high (82%). Stunting rate was very high (72% and 69% in the subgroup) as well as underweight (21%).

Almost all mothers (90%) reported that it was very important that both fathers and mothers talk to their infants, play with their infants at least once a day, and spend time with their infants in activities (appendix 5). Household items, such as kitchen utensils (75%), and materials from outside the house, such as wooden stick (71%), were common children's toys (figure VII.1). Children had little variety of play materials (figure VII.2). More elaborate toys such as those made for building or constructing (8%) and toys for pretending (26%) were less common. More than two-thirds (> 69%) of the mothers reported that an adult is talking to their infants, or sit with

their infants during meals, or play with their infants almost every day (figure VII.3); but, singing songs or reading books was less common.

Scaled child development scores were low across all domains (table VII.3). Mean cognitive score was very low [mean (SD): 2 (2)] compared to the average score of 10. The mean scaled expressive language score was even lower [2 (2)]. Likewise, children performed poorly across the cognition [60 (10)], motor [62 (13)], and language [62 (13)] domains, compared to the average for their age of 100. Although still below the average, socioemotional composite scores development were higher [85 (18)] than the other domains.

Stunted and underweight children tended to have lower composite cognitive and language scores compared to children with normal length and weight, although not statistically significant (table VII.4). Additionally, children with better feeding practices tended to have higher scores in the motor and cognition domains, but the results also did not reach statistical significance. Stunted children had significantly higher composite socioemotional scores than non-stunted children. Also, children achieving the MMF had significantly higher socioemotional scores. No significant difference was found across the other feeding practices.

Only gross motor raw scores were not positively significantly correlated with any other development domains (figure VII.4). The strongest significant correlation was between fine motor and cognition ($r = 0.69$). The significant correlation coefficients ranged from 0.33 to 0.69.

4. Discussion

Children in our sample had extremely low cognitive, motor, and language development scores, which exceeded 2 SD below the mean of standardized scores for the children with the same age. The scores were also lower than reports from other LMICs [21, 22]. Although our

sample may not be representative of the whole Vakinankaratra region, these results provide a view of the extent of the child development deficits in rural areas of Madagascar.

Contrary to results from other LMICs showing positive associations between child length and development [9-11, 23], we did not find significant differences in cognition, language, and motor scores between stunted and non-stunted children. This study may not have enough power to detect significant differences in child development across nutritional status. Nevertheless, we see a pattern showing lower cognition and language skills among stunted and underweight children compared to children with optimal growth. There is no clear explanation regarding stunted children having significantly higher socioemotional development scores in our sample. Positive linear association has been reported between length and development in Tanzanian children, suggesting that shorter children are more likely to experience developmental deficits [11]. In our sample, the very low mean LAZ (-2.50) suggest that most infants are shorter than their age, thus at high risk of impaired development.

Also, no statistically significant difference was seen in cognition, language, and motor development scores of children based on complementary feeding practices. Although appropriate nutrient intake is a requirement for brain and muscle development, other factors such as adequate and age-appropriate stimulation are also needed [3, 24].

Most of the children's toys were items from the household or objects from outside the home, none of which were specifically designed for child stimulation. Children also had a limited variety of play materials, mainly toys that make noise. A wide variety of toys has been shown to be strongly associated with improved child development [10, 25]. Accessibility to various play materials that increase child stimulation such as picture books, toys for learning shapes, and toys for pretending would likely benefit the children.

The mothers' reported positive attitude towards child stimulation can be an opportunity to promote child development. Almost all mothers acknowledged the importance of parent-child interaction through dialogues, interactive play and learning activities. Parents who are aware of the connection between their interaction with their children and their development are more likely to engage in practices that promote stimulation [26]. Additionally, in most households, adults were reported to engage in play activities with the child almost every day. A variety of adult-infant interaction has been associated with better stimulation practices and then higher developmental outcomes in children [10]. Parents and other caregivers in the family need to be encouraged to diversify the type of activities they participate in with the child every day.

The findings that cognition, fine motor, and language scores are positively correlated with each other suggest that improving one of these developmental domains may be beneficial to other domains. For example, activities promoting fine motor skills and encouraging children to express themselves vocally and verbally could potentially improve their cognition in our study sample.

The very high stunting rate in the Vakinankaratra region combined with the very low performance on child development tests along with the observed limited resources for stimulation require urgent attention. Combining efforts to prevent both undernutrition and developmental delay during the first two years in at risk children has received much interest [12, 27]. However, results from integrated child nutrition and psychosocial stimulation interventions showed that improvements in growth do not always lead to better developmental outcomes [27, 28]. A recent cluster randomized trial in southeastern Madagascar showed no effect on developmental outcomes of an intensive counseling package on complementary feeding and child stimulation [29].

Nevertheless, the opportunity of addressing growth faltering and promoting optimal development during the early years should not be missed, especially in areas with high burdens of child undernutrition. The Nurturing Care framework suggested by the most recent Lancet series on Early Child Development integrates maternal and child health and nutrition as well as aspects of child protection and safety [4]. Most interventions combined only improved nutrition and child stimulation components, but broadening the scope of action may be more effective [30]. For example, a parenting intervention consisting of peer group discussions and interactive learning activities on general child care (nutrition, hygiene, stimulation, and love) along with maternal psychological wellbeing in Uganda had positive effects on child development [31].

Although this study is the first, to our knowledge, to assess child development in the Vakinankaratra region, our results should be interpreted with caution. First, although the Bayley's Scales have been widely used to assess child development across various populations, they have not been validated in the Malagasy population. Translating and adapting the entire Bayley's scale were beyond the scope of this study. Also, we only assessed a subsample of children 11 to 13-month-old. Although different age groups may perform differently in child development tests, previous studies reported low scores in language and cognitive skills among Malagasy children older than 2 years [14, 15]. Mothers may not necessarily think about all the questions pertaining to children's behavior that were included in the questionnaire. Also, recall bias and social desirability are possible for the socioemotional assessment.

5. Conclusion

Cognition, motor, language, and socioemotional development scores of subsamples of young children under two years in the Vakinankaratra region were very low. Although there were no statistically significant differences in developmental outcomes based on nutritional status,

multi-sectorial and integrated efforts are needed to tackle both undernutrition and poor development. Implementing interventions early in infancy, taking advantage of the rapid growth and the high neural plasticity during the early years, is critical to promote growth and development in low-income settings.

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Table VII.1. Characteristics of the study population.

Groups		Socioemotional development assessment		Cognitive, motor, and language assessment subgroup
Variables	**N**	**Frequency or mean (SD)**	**N**	**Frequency or mean (SD)**
Child characteristics				
Age (months)				
11	33	43	13	36
12	29	38	12	33
13	14	19	11	31
Sex				
Male	37	49	18	50
Female	39	51	18	50
Birthweight				
< 2500 g	47	21	10	28
≥ 2500 g	29	79	26	72
Maternal characteristics				
Age	76	27 (6.5)	36	27 (7)
Education				
No formal education	2	3	1	3
At least some primary	40	53	17	47
At least some secondary	30	39	14	39
Higher	4	5	4	11
Household characteristics				
Household size	76	4 (1.4)	38	4 (1.3)
Use of iodized salt				
No	36	48	17	47
Yes	39	52	19	53

Table VII.2. Complementary feeding practices and nutritional status of the young children.

Feeding practices	Socioemotional subgroup		Cognitive, motor, and language subgroup	
	N	Mean	N	Mean
Minimum dietary diversity				
No	47	62	21	55
Yes	29	38	17	45
Minimum meal frequency				
No	14	18	7	18
Yes	62	82	31	82
Minimum acceptable diet				
No	50	66	23	60
Yes	26	34	15	39
Consumption of iron-rich foods				
No	65	85	33	87
Yes	11	15	5	13
Nutritional status				
Stunting	55/76	72	25/38	69
Underweight	16/76	21	4/32	12
Wasting	3/76	4	0/32	0

Figure VII.1. Source of play materials in young children aged 11 – 13 months (%, n = 36).

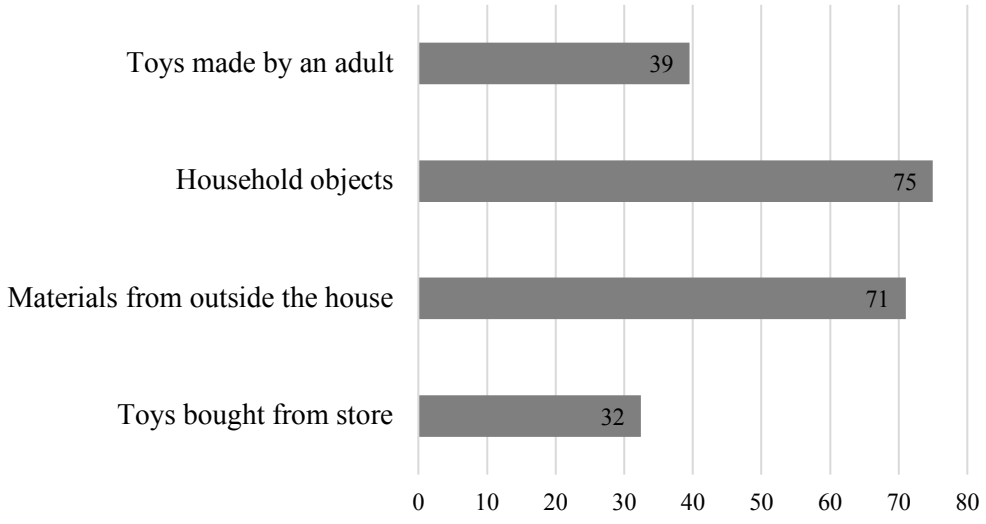


Figure VII.2. Variety of play materials in young children aged 11 – 13 months (%, n = 36).

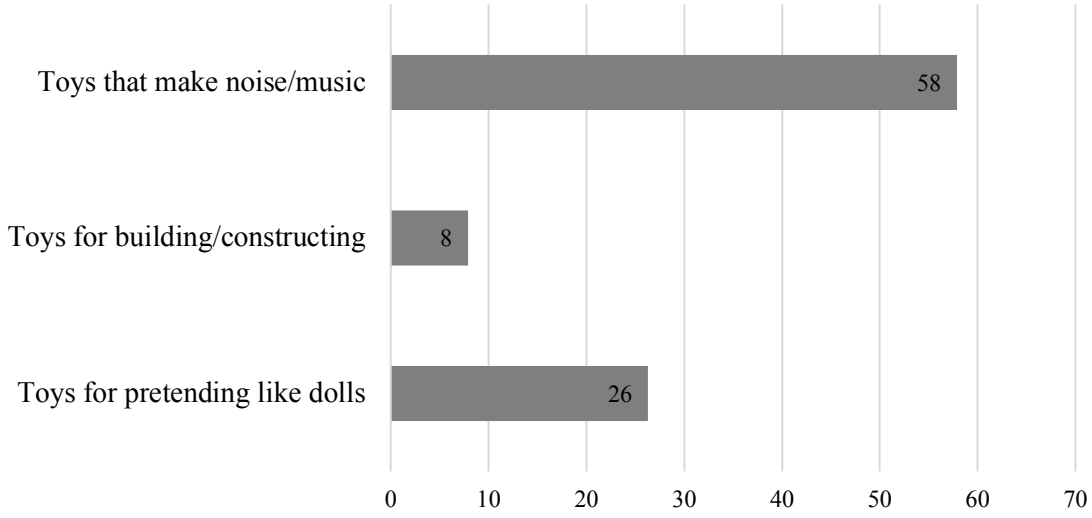


Figure VII.3. Frequencies of play activities frequencies in young children aged 11 – 13 months (%, n = 36).

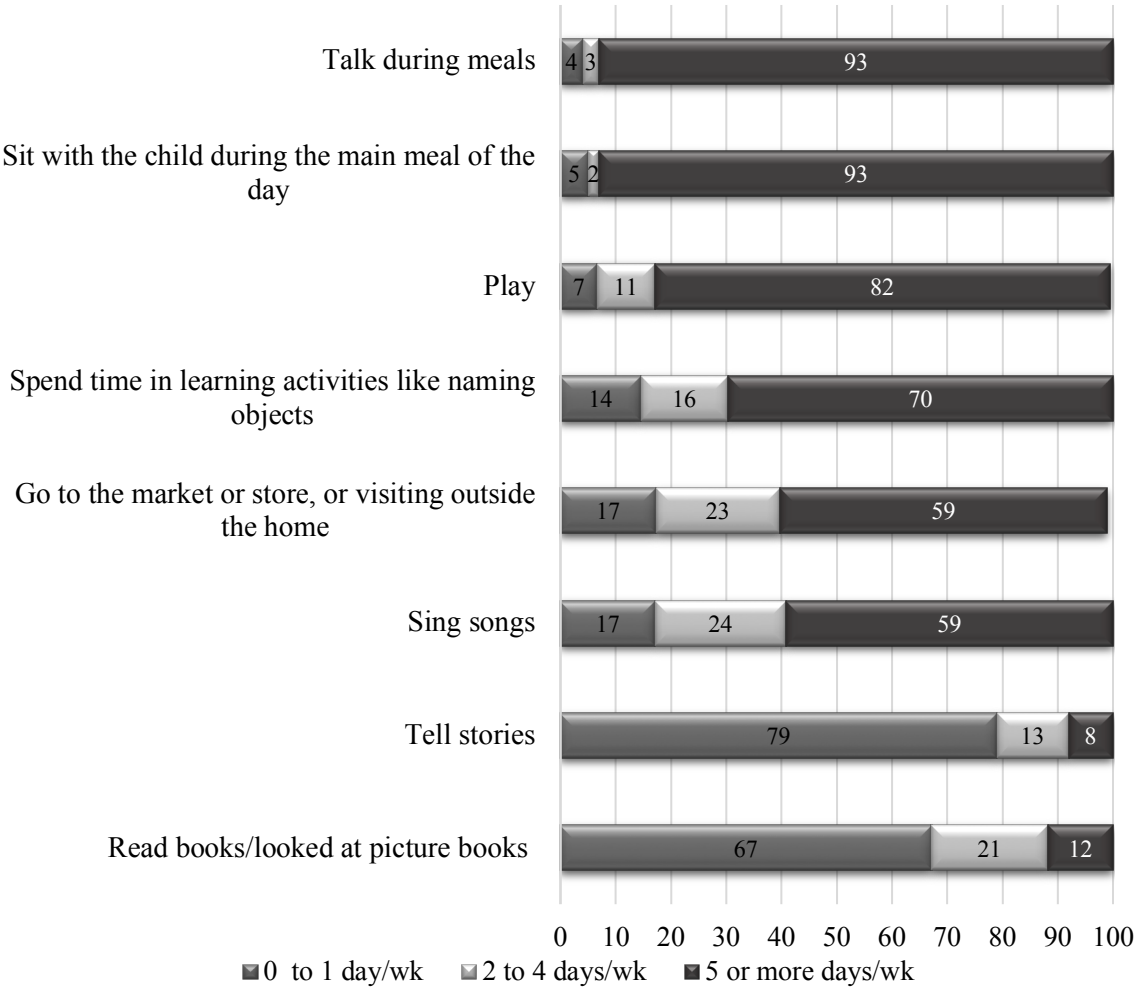


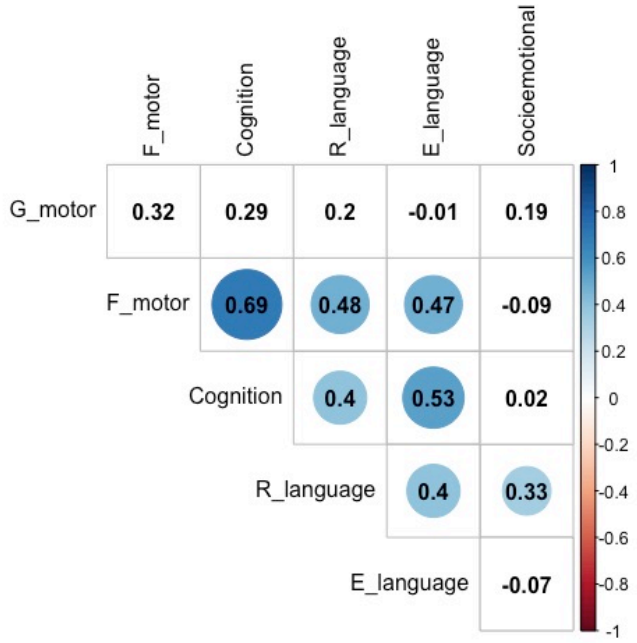
Table VII.3. Mean (SD) Bayley's Scales development scores for each domain.

Domain/subdomain	N	Raw score	Scaled score (0 – 19)	Composite score (40 – 160)
Cognitive	36	26 (4)	2 (2)	60 (10)
Gross motor	36	31 (6)	4 (2)	-
Fine motor	36	21 (4)	3 (3)	-
Motor domain	36	-	7 (4)	61.9 (13)
Receptive language	36	9 (4)	5 (3)	-
Expressive language	36	2 (2)	2 (2)	-
Language domain	36	-	7 (4)	62 (13)
Socioemotional	76	64 (11)	7 (4)	85 (18)

Table VII.4. Mean composite Bayley's Scales composite development scores by nutritional status and complementary feeding practices (n = 76).

Scores	Cognitive	Motor	Language	Socioemotional
Stunting				
No	60	61	62	78[a]
Yes	60	62	62	88[b]
Underweight				
No	61	62	63	84
Yes	55	63	55	90
Minimum dietary diversity				
No	59	63	60	83
Yes	61	61	64	88
Minimum meal frequency				
No	61	66	67	75[c]
Yes	60	61	61	87[d]
Animal source food consumption				
No	59	62	62	85
Yes	63	60	63	83
Minimum acceptable diet				
No	60	63	61	82
Yes	60	60	63	90

[a]Results with different letters are significantly different ($p < 0.05$)



Correlation coefficients within circles are statistically significant ($p < 0.05$).

G_motor: Gross motor; F_motor: Fine motor; R_language: Receptive language; E_language: Expressive language.

Figure VII.4. Correlation coefficients between the child development scores per domain (n = 36).

CHAPTER VIII

SUMMARY, CONCLUSIONS, AND FUTURE RESEARCH RECOMMENDATIONS

The purpose of this study was, first, to investigate the factors associated with child undernutrition and its association with poor development in Vakinankaratra region of Madagascar. The influence of maternal knowledge and practices of complementary feeding on child growth were also analyzed. Second, this study also aimed to explore the attitudes of parents and the community regarding fathers' involvement in child care.

Key findings and implications

Although only 63.9% knew that infants should be exclusively breastfed for the first six months, mothers in the Vakinankaratra region otherwise had relatively good knowledge regarding complementary feeding. However, suboptimal feeding practices were still observed, especially for minimum dietary diversity (35.8%) and consumption of iron-rich foods (14.1%). Our qualitative data showed that barriers to optimal feeding practices were present at the individual (mother), the household, and the community levels. Food insecurity and large family size also prevented mothers from having appropriate feeding practices. And rumors regarding foods not to be given to infants were still present (beans, egg yolk, sometimes milk).

Optimal complementary feeding practices as assessed using the WHO IYCF indicators were not significantly associated with stunting and wasting. Only consumption of iron-rich foods and higher maternal knowledge of complementary feeding were associated with lower odds of underweight. Nevertheless, efforts to improve feeding practices in the Vakinankaratra region are needed given the low proportions of minimum dietary diversity and iron-rich food consumption. Nutrition education may be effective as higher maternal knowledge of complementary feeding was associated with better practices. However, interventions will have greater impact if the identified barriers are addressed. Also, considering the enablers of optimal feeding practices when designing such interventions will be helpful. Mothers had perceived benefits of giving their children diversified complementary foods. Additionally, they were able to make the connection between adequate foods and child growth, and sometimes development. Thus, in reference to the transtheoretical model, mothers in the Vakinankaratra region may be categorized in the contemplation stage of change.

Our results may be used to design theory-based interventions to improve feeding practices in the region. For example, the social ecological model could be used to address the barriers at different levels and facilitate optimal feeding practices. The finding that mothers trust and respect the CNAs, from whom they seek advice, suggests that implementing the interventions within the local structure and/or involving the CNAs may potentially increase success.

Involving fathers may be a potential way to decrease maternal workload and increase time for child and personal care. However, our findings indicated strong traditional gender roles regarding child care were a recurring theme and these were identified as a barrier to fathers' involvement. Child caregiving is perceived as women's responsibility and men were expected to provide financial resources. In addition, fathers reported teaching, playing, and supporting mothers with household chores as their responsibilities. In practice, fathers were mostly involved in playing, teaching, and spending time with children. Fathers would engage in feeding and help

with chores when mothers were unavailable. However, fathers involved in child care activities and household work may be criticized and teased by other men. Similarly, wives of involved fathers were usually perceived as lazy and unable to take care of her children. Nevertheless, mothers usually saw fathers' involvement positively and they were enthusiastic about having their husbands/partners engaged in child care activities.

There are opportunities to increase fathers' involvement in the Vakinankaratra region. Fathers, as well as mothers, expressed the will to be more engaged in child care activities. Despite strong traditional gender roles, some fathers were participating in activities related to child care. Fathers also identified the perceived benefits of stimulating activities (playing and teaching) on child development. In addition to increasing awareness regarding gender role perceptions in child care, other barriers of fathers' involvement need to be addressed. Fathers' work and related factors including lack of time, separation, and being tired after work, were the main barriers. To a lesser extent, lack of willingness and fathers not being prepared were also identified as barriers to involvement. Strategies to increase fathers' participation may be more effective if based on theories of behavior change using our findings. For example, the social cognitive theory could be used as changes in the environment, such as community perceptions (or outcome expectations), and within the person, such as confidence (or self-efficacy), would likely facilitate the desired behavior.

Our analysis of the sociodemographic factors associated with child growth supports the well acknowledged multifactorial aspects of child undernutrition. Reducing the very high stunting rate of 69.4% and underweight prevalence of 23.4% in children under two in the Vakinankaratra region will require evidence-based nutrition-specific and nutrition-sensitive interventions. The finding that birthweight predicted child length, weight, and weight-for-length reinforce the importance of nutrition before and during pregnancy.

Increased child age was another immediate factor associated with lower length and weight, emphasizing the rapid growth decline in children in the 6 – 23 months age group. Additionally, maternal height predicting both LAZ and WAZ supports the partial role of genetics and the intergenerational aspect of undernutrition. And larger household size was associated with lower length and weight. Significant differences in LAZ and WLZ were also found across communes of residence, which could be explained by differences in the delivery of the national nutrition program as well as community-levels factors such as access to health care and information. In the final models, fathers' involvement, as assessed in this study, was not associated with any growth indicators.

Our results suggest the need for integration of multiple sectors including health and agriculture to reduce the high burden of child undernutrition in the Vakinankaratra region. For example, interventions to promote crop diversification, especially micronutrient-rich fruits and vegetables, combined with nutrition education sessions may address concurrently the lack of ingredients for complementary food and the identified perceptions of some foods being heavy for children. Also, in addition to the nutrition education offered by the CNAs, reinforcing the importance of breastfeeding and appropriate complementary feeding during antenatal and postnatal care sessions may be needed. As suggested by the literature, early interventions could give an advantage when promoting child growth. For example, improving service delivery and quality as well as the accessibility of antenatal care may be helpful.

Assessment of the developmental outcomes in a subsample of children aged 11 – 13 months showed low scores across the cognitive, language, motor, and socioemotional domains. Cognitive scores were the lowest among all domains and socioemotional scores were the highest, but still below the average compared to other children in the same age group. The low developmental scores in the subsample confirms the link between child undernutrition and development in low-income settings.

There is an opportunity to promote child development in the Vakinankaratra region as mothers acknowledge the importance of regular child stimulation activities such as talking and playing. However, potential barriers need to be identified and addressed. In addition to the lack of time for child care due to heavy workload reported by mothers, lack of resources for play materials may also be a problem. Most families use household objects and materials found outside the home as children's toys. There was also very limited variety in play materials. A possible solution could be working with child development specialists to help parents design or adapt available materials to make appropriate toys for optimal stimulation for different age groups. Such interventions could be implemented in form of a parenting school program, which would also give an opportunity to promote child nutrition and fathers' involvement in child care. Greater fathers' involvement in child care could also allow mothers to have more time to specifically interact with their children.

Future research directions

Although our results provide insights about the complementary feeding knowledge, attitudes, and practices in the Vakinankaratra region, more research is needed to evaluate detailed nutrient intakes of children. One of the limitations of the WHO IYCF indicators is their lack of specificity. More comprehensive assessments of nutrient adequacy such as weighed food records are warranted. Because breastmilk is still an important source of nutrients for children under two, having detailed information about breastfeeding practices such as quantity consumed, or daily frequency and length of each episode would be helpful in explaining potential nutrient gaps in this age group. Also, multiple nutrient intake assessments are necessary due to the seasonal changes in food availability.

Developing and validating tools to assess fathers' involvement in child care more accurately are also needed to comprehensively evaluate its potential to enhance child growth and development. In addition to the participation of fathers in various activities, studies on time use of fathers and mothers relating to child care activities may provide additional insights on fathers' involvement.

Additionally, this study focused on the complementary feeding period (6 – 23 months) but undernutrition, especially stunting, is likely to start earlier. A prospective cohort study following mothers from early pregnancy through the first year will add to the understanding of the impacts of the risk factors on child growth in the region. Such studies will evaluate the role of maternal nutrition during pregnancy and breastfeeding patterns, as well as early complementary feeding practices.

Additional assessment of child development using different tools should be conducted to confirm our results. Such tools are needed for both research and practice to document and monitor the impact of interventions. Finally, more research on the role of individual nutrients, such as iodine and iron on different domains of child development would be interesting to investigate among children in the Vakinankaratra region.

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APPENDICES

Appendix 1. WHO Infant and Young Children Feeding (IYCF) indicators [58].

Indicator	Definition	Children included
Early initiation of breastfeeding	Proportion of the infants alive or deceased who were put to breast milk within one hour after birth.	Children born in the past 24 months
Exclusive breastfeeding under 6 months	Proportion of infants who were exclusively fed with breast milk for the first 5 months	Infants aged 0-5 months who received only breast milk the previous day
Continued breastfeeding at 1 year	Proportion of children aged 12-15 months who were fed breast milk	Infants aged 12-15 months who received breast milk the previous day
Introduction of complementary foods	Proportion of children who received solid, semi-solid or soft foods	Infants aged 6-8 months who received solid, semi-solid or soft foods the previous day
Minimum dietary diversity	Proportion of children who received foods from 4 or more food groups	Children aged 6-23 months who received foods from 4 or more food groups the previous day
Minimum meal frequency	Proportion of children who received solid, semi-solid or soft foods the minimum number of times - 2 times for breastfed infants 6-8 months - 3 times for breastfed children 9-23 months - 4 times for non-breastfed children 6-23 months	Children aged 6-23 months (breastfed or not) who received solid, semi-solid or soft foods the minimum number of times the previous day

Minimum acceptable diet	Proportion of children aged 6-23 months, breastfed or not, who received a minimum acceptable diet (minimum meal frequency and minimum dietary diversity)	For non-breastfed children, those who received at least 2 milk feedings and had at least the minimum dietary diversity and the minimum meal frequency during the previous day
Consumption of iron-rich or iron-fortified foods	Proportion of children who received iron-rich or iron-fortified foods	Children aged 6-23 months who received iron-rich or iron-fortified foods the previous day

Appendix 2. Sampling details: Districts, communes, and fokontanys selected for the study.

Districts	Communes	Fokontanys	Number of households
Antanifotsy	Antanifotsy	Andohafarihy	8
		Andriantsilahy	8
		Anondrilahy	8
		Antanambao	7
		Antanety Nord	7
		Antemotra	9
		Antsahamaina	8
		Fierenana	7
		Mahalavolona	8
		Morarano III	7
		Total	77
	Ampitatafika	Amboniandrefana	9
		Masoandro	12
		Tsarahonenana	12
		Total	33
	Ambohimandroso	Antsapandrano	10
		Maromoka Centre	8
		Maromoka Fonenantsoa	10
		Total	28
Antsirabe II	Ambohibary	Ampetsapetsa	9
		Ankeniheny	9
		Antsofombato	9
		Sahabe	15
		Total	42
	Ambohidranandriana	Ambohimarina	8
		Anosibe	8
		Antsahavory	8
		Miarinarivo	8
		Soamonina	8
		Total	40
	Andranomanelatra	Ambohimandroso	10
		Andranomanelatra	10
		Morarano	11
		Tsaravavaka	10
		Tsarazazamandimby	10
		Total	51
	Antanimandry	Ambohidrano	10
		Andrianana	10
		Antanimandry	10
		Antsongombe	10

		Total	40
Antsirabe II	Ibity	Ambalavao	9
		Ambarinakanga	8
		Apopoha	6
		Ihasy	8
		Mananjara	11
		Total	42
	Mandrosohasina	Mandrosohasina	17
		Tongasoa Ambanimaso	10
		Tsaramody	11
		Total	38
	Total participants		**391**

Appendix 3. Questionnaire.

Section 1: SOCIODEMOGRAPHIC CHARACTERISTICS

Instruction: circle the responses from the given option and write if any other idea or answer is given.

No	Question	Response
101	Age	
102	What is your main occupation?	0. Housewife 1. Farmer 2. Office employee (government or non-government) 3. Others_____
103	What is your highest educational level?	0. Illiterate 1. Informal education 2. Formal education_____years 3. Higher education
104	Who is the head of the household?	0. Father 1. Mother (yourself) 2. Other (specify)_____
105	How many individuals live in house permanently? (family size)	
107	Does your household own agricultural land?	0. Yes 1. No
108	What is the size of your land? (add unit)	
109	Does your household have any animals?	0. Yes 1. No
110	What types and how many animals? (Put numbers after each animal)	0. Bull 1. Cow 2. Pig 3. Sheep 4. Poultry 5. Others (specify)_____
111	What is the main source of your drinking water?	0. Rivers and lakes 1. Tube wells 2. Rainwater 3. Public tap water 4. I don't know
112	How long is the walk to the water source?	
113	Who is in charge of fetching water?	0. Mother 1. Father 2. Daughter/son 3. Other (specify)_____
114	What sanitation facility do you have?	0. Latrines 1. None 2. Other (specify)_____
114a	If latrines, do you share it with other households?	0. Yes 1. No

114b	If yes, with how many other households do you share the latrine?	
115	How old were you when you first gave birth?	
116	How many living children do you have?	
117	How many children live in your household?	
117a	How old are they?	
118	For this last pregnancy, how many antenatal visits have you attended?	
119	For this last birth, where did you deliver?	0. Hospital 1. Local public health center 2. Private health center 3. Home 4. Other (specify)_____
120	For this last birth, how many postnatal checks have you gone to?	
121	For this last birth, how big was your baby?	0. Very small 1. Smaller than average 2. Average 3. Larger than average 4. Very large 5. Don't know
122	Have you met a health staff in the last 3 months?	
123	Has your last child had diarrhea recently?	0. No 1. Yes, in the last 24 hours 2. Yes, in the last 2 weeks 3. I don't know
124	Has your last child had cough recently?	0. No 1. Yes, in the last 24 hours 2. Yes, in the last 2 weeks 3. I don't know
125	Has your last child had fever recently?	0. No 1. Yes, in the last 24 hours 2. Yes, in the last 2 weeks 3. I don't know
126	Did your child receive Vitamin A supplements in the last 6 months?	0. Yes 1. No
127	Did your child receive a de-worming treatment in the last 6 months?	0. Yes 1. No
128	For the last week, how many times have you listened to the radio?	0. I have not listened to the radio 1. Once or twice 2. Almost every day
129	For the last week, how many times have you read the newspaper?	0. I have not read the newspaper 1. Once or twice 2. Almost every day
130	For the last week, how many times have you watched the TV?	0. I have not watched the TV 1. Once or twice 2. Almost every day

131	Do your household own any of these items?	0. Cellphone 1. Bike 2. Lantern/flashlight 3. Radio 4. Ox cart 5. Functioning CD/DVD player
132	How many rooms do you have in your house?	
133	What is your floor made of?	0. Mud 1. Cement 2. Wood 3. Other
134	What type of house do you live in?	0. Wooden house 1. Mud house 2. Brick house 3. Other
135	Does your household use iodized salt?	0. Yes 1. No

SECTION 2: Household Food Insecurity Access Scale (HFIAS)

Instruction: circle the responses from the given option.

No	Question	Response
201	In the past four weeks, did you worry that your household would not have enough food?	0 = No (skip to 203) 1= Yes
202	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)
203	In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	0 = No (skip to 205) 1= Yes
204	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)
205	In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?	0 = No (skip to 207) 1= Yes

206	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)
207	In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	0 = No (skip to 209) 1= Yes
208	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)
209	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	0 = No (skip to 211) 1= Yes
210	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)
211	In the past four weeks, did you or any other household member have to eat fewer meals in a day because there was not enough food?	0 = No (skip to 213) 1= Yes
212	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)
213	In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?	0 = No (skip to 215) 1= Yes
214	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)
215	In the past four weeks, did you or any household member go to sleep at	0 = No (skip to 217) 1= Yes

	night hungry because there was not enough food?	
216	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)
217	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = No 1 = Yes
218	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)
219	How long did last year's rice production last?	

SECTION 3: COMPLEMENTARY FEEDING KNOWLEDGE

Instruction: circle the responses from the given option.

No	Question	Response
301	Where did you receive information about complementary feeding? (Circle all that apply)	0. Health/community workers 1. Family members 2. Media 3. Other 4. Nowhere
302	Other than breastmilk, what should infants be given during the first 6 months?	0. Hot water 1. Sugary water 2. Nothing, breastmilk only 3. Soft foods 4. Other (specify)_____ 5. I don't know
303	When should breastfeeding stop?	0. 6 months 1. 12 months (1 year) 2. 18 months (1 year and half) 3. 2 years or more 4. I don't know
304	At what age should an infant be introduced to complementary feeding?	0. < 4 months 1. 4 - 6 months 2. 6-8 months

		3. > 8 months 4. I don't know
305	Does it matter if the child is looked at in the eyes during feeding?	0. Yes 1. No
306	Does it matter if the child is forced to finish the plate when you feed him/her?	0. Yes 1. No
307	Does it matter if the child is talked to when you feed him/her?	0. Yes 1. No
308	Does it matter if child is rushed to eat fast during feeding?	0. Yes 1. No
309	What should a 6 months old child be fed?	0. Soft foods (mashed or puree) 1. Semi-solid foods (watery rice) 2. Family foods 3. I don't know
310	How many times a week does an infant need to consume meat, poultry, and/or fish?	0. Once a week 1. Three times a week 2. Every day 3. They can't eat these
311	How many times a week does an infant need to consume eggs?	0. Once a week 1. Three times a week 2. Every day 3. They can't eat eggs
312	How often should a 6 – 8 months child fed in a day?	0. Once 1. 2 – 3 times 2. 4 – 5 times 3. I don't know
313	How often should a 9 – 11 months child be fed in a day?	0. 2 times 1. 3 – 4 times 2. 5 – 6 times 3. I don't know
314	When can a child eat family foods without modification?	0. 6 months 1. 12 months 2. 18 months 3. I don't know

SECTION 4: COMPLEMENTARY FEEDING PRACTICES

Instruction: Ask the following questions to the mother (or the caregiver) about their child aged 6-23 months. All of the questions relate to that child.

No	Questions	Response
401	What is his/her birthday? If the respondent does not know the exact birthdate, ask: Does he/she have a health/vaccination card with the birthdate recorded? If the health/vaccination card/official document is shown and the respondent confirms the information is correct, record the date of birth as documented on the card. Also, record the birthweight if indicated.	
402	How many months old is your child?	
403	Check consistency (vaccination card, yellow booklet)	
404	Was your child breastfed yesterday during the day or at night?	
405a	Next, I would like to ask you about some liquids that your child may have had yesterday during the day or at night. Did he/she have any…: Plain water?	0. No 1. Yes
405b	Infant formula such as Nutricia, Gallia, etc.?	0. No 1. Yes
405c	Milk such as tinned, powdered, or fresh animal milk?	0. No 1. Yes
405d	Juice or juice drinks?	0. No 1. Yes
405e	Clear broth?	0. No 1. Yes
405f	Yogurt?	0. No 1. Yes
405g	Thin porridge?	0. No 1. Yes
405h	Any other liquids? (specify)	0. No 1. Yes

414	Please describe everything that your child ate yesterday during the day or night, whether at home or outside the home. For each meal, put bullet points. a) Think about when (NAME) first woke up yesterday. Did (NAME) eat anything at that time? If yes: Please tell me everything (NAME) ate at that time. Probe: Anything else? Until respondent says nothing else. If no, continue to Question b). _____ _____

	b) What did he/she do after that? Did he/she eat anything at that time? If yes: Please tell me everything he/she ate at that time. Probe: Anything else? Until respondent says nothing else. _____ _____ Repeat question b) above until respondent says the child went to sleep until the next day. _____ _____ If respondent mentions mixed dishes like a porridge, sauce or stew, probe: c) What ingredients were in that (MIXED DISH)? Probe: Anything else? Until respondent says nothing else. _____ _____

Section 5: WATER, SANITATION, AND HYGIENE KNOWLEDGE

Instruction: circle the responses from the given options.

No	Question	Response
501	What is the safest source of drinking water for children?	0. Rivers and lakes 1. Tube wells 2. Rainwater 3. Public tap water 4. I don't know
502	What should be done before giving water to children?	0. Nothing 1. Warm it up 2. Boil 3. Add *Sur'Eau* or other treatment agents 4. I don't know
503	How should drinking water be stored?	0. Covered 1. Not covered but in a clean area 2. Not covered 3. I don't know
504	What should be cleaned before feeding your baby?	0. The caregiver's hands only 1. The caregiver's hands and the baby's hands 2. The caregiver's hands, the baby's hands and the utensils 3. Nothing

		4. I don't know
505	Should you wash your hands before preparing food?	0. Yes 1. No
507	Should you wash your hands after cleaning the child's bottom?	0. Yes 1. No
508	Should you wash your hands after defecation?	0. Yes 1. No

How important are these statements regarding children's hygiene to you?

No	Statement	Response
509	Children need to have a clean space to crawl	0. Not important 1. Somewhat important 2. Very important
510	Flies and mosquitoes should be avoided in the house	0. Not important 1. Somewhat important 2. Very important
511	Chickens should not be kept in areas where children play	0. Not important 1. Somewhat important 2. Very important
512	Children should sleep under bed nets	0. Not important 1. Somewhat important 2. Very important
513	Children's feces should be removed safely	0. Not important 1. Somewhat important 2. Very important
514	If yes, how?	

Section 6: WATER, SANITATION, AND HYGIENE PRACTICES

Instruction: observe the spot-checks and take note as per observed (circle what applies).

No	Spot	Response
601	Mother clean	0. No 1. Yes
602	Child clean	0. No 1. Yes
603	Diaper/bottom clean	0. No 1. Yes
604	Compound clean	0. No 1. Yes
605	Poultry feces in the house	0. No 1. Yes
606	Baby feces in the house	0. No 1. Yes

607	Water standing in the surroundings	0. No 1. Yes
608	Unwashed utensils	0. No 1. Yes
609	Drinking water covered	0. No 1. Yes
610	House swept	0. No 1. Yes
611	Garbage container in house	0. No 1. Yes

SECTION 7: CHILD STIMULATION KNOWLEDGE

Instruction: circle the responses from the given option.

How important are these statements regarding children to you?

No	Statement	Response
701	Mothers need to talk to their infants	0.Not important 1.Somewhat important 2.Very important
702	Mothers need to play with their children at least once a day	0.Not important 1.Somewhat important 2.Very important
703	Mothers need to spend time in learning activities with their infants	0.Not important 1.Somewhat important 2.Very important
704	Fathers need to talk to their infants	0.Not important 1.Somewhat important 2.Very important
705	Fathers need to play with their children at least once a day	0.Not important 1.Somewhat important 2.Very important
706	Fathers need to spend time in learning activities with their infants	0.Not important 1.Somewhat important 2.Very important

Section 8: CHILD HOME STIMULATION

Instruction: circle the responses from the given options.

No	Question	Response
801	Children seem to demand attention when their parents are busy, doing housework, for example. Do you	1.No 2.Yes

	usually respond to your child's demand for attention while you are working?	
802	Has your child done anything in the last week that pleased you very much?	0. No 1. Yes
803	If yes, what?	
804a	What kinds of things do you have your child play with? Toys made by an adult	0. No 1. Yes
804b	Household objects	0. No 1. Yes
804c	Materials from outside the house	0. No 1. Yes
804d	Toys that make noise	0. No 1. Yes
804e	Toys for building things	0. No 1. Yes
804f	Toys for pretending like dolls	0. No 1. Yes
804g	Other (specify)	
805a	In the past week, on how many days did any adult in the family do the following with your child? (specify number) Read books or look at picture books	
805b	Tell stories	
805c	Sing songs	
805d	Go to the market or store, or visiting outside the home	
805e	Play	
805f	Spend time in learning activities like naming objects	
805g	Sit with the child during the main meal of the day	
805h	Talk during meals	
806	How do you know when your child is hungry? Circle all that apply	0. Cries 1. Asks for food, points, or uses gestures (but does not cry) 2. Other (specify)_____
807	When you serve your child food, how is it served?	0. Separate bowl 1. Common or shared family plate 2. Child has not started eating other foods
808	What do you usually do to get your child to eat? Circle all that apply	0. Nothing 1. Tell child to eat 2. Encourage, praise, play or hold 3. Give other types of food 4. Force, threaten, or hit 5. Other (specify)_____

SECTION 9: FATHER'S INVOLVEMENT IN CHILD CARE

Instruction: circle the responses from the given options. How often does your husband/partner…?

No	Questions	Response
901	Contribute money to support the child regularly, paying for food	0. Never 1. Sometimes 2. Almost always
903	Take the child to healthcare center since his/her birth, alone or with you	0. Never 1. Sometimes 2. Almost always
903	Play and talk with the child daily	0. Never 1. Sometimes 2. Almost always
904	Feed and take care of the child almost daily	0. Never 1. Sometimes 2. Almost always
905	Hold and carry the child daily	0. Never 1. Sometimes 2. Almost always
905	Teach things to the child	0. Never 1. Sometimes 2. Almost always
906	Take care of the child when you are busy	0. Never 1. Sometimes 2. Almost always
907	Advice you on matters regarding the child	0. Never 1. Sometimes 2. Almost always

SECTION 10: SOCIO-EMOTIONAL DEVELOPMENT [11-13 months only]

Instruction: circle the responses from the given options.

How often do you observe these…?

No	Question	Response
1001	Takes a calm and enjoyable interest in most sounds	0. Can't tell 1. None of the time 2. Some of the time 3. Half of the time 4. Most of the time 5. All of the time
1002	You can easily get your child's attention without having to be very dynamic	0. Can't tell 1. None of the time 2. Some of the time 3. Half of the time 4. Most of the time 5. All of the time

1003	Takes a calm and enjoyable interest in most sights, including colorful or bright things	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1004	You can easily get your child to look at things without them being very bright or colorful	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1005	Calmly enjoys touching or being touched by different things	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1006	You can easily get your child to respond to your touch without having to touch your child firmly to get his attention	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1007	Likes to be swung around, danced with while in your arms, or quickly lifted up in the air	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1008	You can easily get your child's attention by approaching him or her, or moving him or her around slowly	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1009	You can help your child to calm down	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1010	Looks at interesting sights, such as your face or a toy	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1011	Looks at or turns toward interesting sounds	0.Can't tell

		1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1012	Seems happy or pleased when he or she sees a favorite person (looks or smiles, makes sounds, or moves arms in a way that expresses joy or delight)	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1013	Responds to people talking or playing with him or her by making sounds or faces (happy sounds or a curious annoyed look)	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1014	Reaches for or points at things, or makes distinct sounds to show you what he or she wants (reaches out to be picked up or points at a toy)	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1015	Exchanges two or more smiles, other looks, sounds, or actions (reaching, giving, or taking) with a favorite person	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1016	Shows you that he or she understands your actions or gestures by making an appropriate gesture in return (makes a funny face back at you, looks at something you point to, stops doing something when you shake your head and use a firm voice to say "no", or smiles and does more of something when you nod with a big smile and say "yes")	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time
1017	Uses many consecutive actions in a back-and forth way to show you what he or she wants or to have fun with you (smiles, reaches out for a hug, and, when you hug, takes your hat, put it on his or her head, and smiles proudly)	0.Can't tell 1.None of the time 2.Some of the time 3.Half of the time 4.Most of the time 5.All of the time

Appendix 4. Sociodemographic variables tested for the prediction of child growth.

Domains	Subdomains	Variables	Types	Range or categories
Immediate causes	Individual factors	Child age	Discrete	6 – 23 months
		Child sex	Dichotomous	Male, female
		Birthweight	Continuous	1200 – 4500 g
	Morbidity	Diarrhea in the past two weeks	Dichotomous	Yes/no
		Cough in the past two weeks	Dichotomous	Yes/no
		Fever in the past two weeks	Dichotomous	Yes/no
	Health services access	Received Vitamin A in the past six months	Dichotomous	Yes/no
		Received deworming in the past six months	Dichotomous	Yes/no
Underlying causes	Maternal factors	Maternal age at first birth	Discrete	14 – 34 years
		Maternal education	Discrete	0 – 15 years
		Maternal occupation	Nominal	Housewife/farmer (+ casual labor)/part-time
		Maternal height	Continuous	125 – 172 cm
		Radio listening over the past week	Ordinal	Didn't listen/once or twice/almost everyday
		Antenatal care attendance	Discrete	0 – 10 times
		Postnatal care attendance	Discrete	0 – 16 times
		Person who delivered	Dichotomous	Medical staff/anybody else
		Place where delivered	Nominal	Hospital or local health center/home
		Met with health staff the past 3 months	Discrete	0 – 12 times
Underlying factors	Fathers' involvement	Financial support	Ordinal	Not at all/sometimes/all the time
		Take child to the health center	Ordinal	Not at all/sometimes/all the time
		Play and talk to child	Ordinal	Not at all/sometimes/all the time

	Fathers' involvement	Feed and take care of child	Ordinal	Not at all/sometimes/all the time
		Hold and carry the child	Ordinal	Not at all/sometimes/all the time
		Teach the child	Ordinal	Not at all/sometimes/all the time
		Take care of the child when mother is busy	Ordinal	Not at all/sometimes/all the time
		Advise the mother	Ordinal	Not at all/sometimes/all the time
	Household factors	Total land size	Continuous	0 – 530 m^2
		Household owns cattle	Dichotomous	Yes/no
		Household owns pig	Dichotomous	Yes/no
		Number of poultries	Discrete	0 – 100
		Number of children under 5	Discrete	0 – 9 children
		Use of iodized salt	Dichotomous	Yes/no
		Wealth index	Ordinal	Lowest/middle/highest
		Food insecurity score	Discrete	0 – 25 (higher scores reflect more food insecurity)
	WASH	Drinking water source	Dichotomous	Unimproved: rivers and lakes, spring water Improved: wells, tube wells, tap water
		Person fetching water	Dichotomous	Mother/anybody else
		Distance from water source	Continuous	1 – 150 minutes
		Shared latrine	Dichotomous	Yes/no
Basic causes		Communes	Nominal	Antanifotsy Ampitatafika Ambohimandroso Ambohibary Ambohidranandriana Andranomanelatra Antanimandry

	Ibity Mandrosohasina

Appendix 5. Maternal perceptions of child home stimulation.

Groups	Socioemotional		Cognitive, motor, and language subgroup	
	N	Frequency (%)	N	Frequency (%)
Mothers need to talk to their infants				
Not important	0	0	0	0
Somehow important	1	1.3	0	0
Very imp	75	98.7	38	100
Mothers need to play with their children at least once a day				
Not important	1	1.32	1	2.63
Somehow important	0	0	0	0
Very important	75	98.7	37	97.37
Mothers need to spend time in learning activities with their infants				
Not important	1	1.3	1	2.63
Somehow important	0	0	0	0
Very important	75	98.7	37	97.37
Fathers need to talk to their infants				
Not important	0	0	1	2.7
Somehow important	1	1.3	0	0
Very important	75	98.7	36	97.3
Fathers need to play with their children at least once a day				
Not important	0	0	3	7.89
Somehow important	3	3.9	0	0
Very important	73	96.1	35	92.11
Fathers need to spend time in learning activities with their infants				
Not important	1	3.9	1	2.63
Somehow important	0	0	0	0
Very important	75	98.7	37	97.37

Appendix 6. IRB Approval from Oklahoma State University.

Oklahoma State University Institutional Review Board

Date:	01/07/2019
Application Number:	HS-18-54
Proposal Title:	Nutrition Adequacy of Complementary Foods in the Highlands of Madagascar
Principal Investigator:	Hasina Rakotomanana
Co-Investigator(s):	
Faculty Adviser:	Barbara Stoecker
Project Coordinator:	
Research Assistant(s):	
Processed as:	Expedited

Status Recommended by Reviewer(s): Approved
Approval Date: 01/07/2019
Expiration Date: 01/06/2020

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

The final versions of any recruitment, consent and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be approved by the IRB. Protocol modifications requiring approval may include changes to the title, PI, adviser, other research personnel, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any unanticipated and/or adverse events to the IRB Office promptly.
4. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact the IRB Office at 223 Scott Hall (phone: 405-744-3377, irb@okstate.edu).

Sincerely,
Oklahoma State University IRB

Appendix 7. Research approval from the Ethics Committee of the Malagasy Ministry of Public Health.

REPOBLIKAN'I MADAGASIKARA
Fitiavana-Tanindrazana-Fandrosoana

MINISTERE DE LA SANTE PUBLIQUE

COMITE D'ETHIQUE DE LA RECHERCHE BIOMEDICALE

N° 010 - MSANP/CERBM

AUTORISATION

Après consultation et avis favorable du Comité d'Ethique de la Recherche Biomédicale auprès du Ministère de la Santé, Mr Hasina RAKOTOMANANA, est autorisé à effectuer la recherche intitulée : **« Explorer les causes de la malnutrition et le retard de développement chez les enfants dans la région Vakinankaratra »** financé par Oklahoma State University.

Antananarivo, le 08 FEV. 2019

Le Ministre de la Santé Publique
Ministère de la Santé Publique
P/o RAKOTONIRINA Julio

VITA

HASINA RAKOTOMANANA

Candidate for the Degree of

Doctor of Philosophy

Thesis: INVESTIGATING THE CAUSES OF CHILD UNDERNUTRITION AND POOR DEVELOPMENT IN VAKINANKARATRA, MADAGASCAR: A MIXED METHODS STUDY

Major Field: Nutritional Sciences

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Nutritional Sciences at Oklahoma State University, Stillwater, Oklahoma in July, 2020.

Completed the requirements for the Master of Science in Nutritional Sciences at Oklahoma State University, Stillwater, Oklahoma in May, 2016.

Completed the requirements for the Master of Science in Chemical Engineering, option Chemistry Applied to the Industry and the Environment at University of Antananarivo in March, 2014.

Completed the requirements for the Bachelor of Science in Agronomy, option: Agricultural and Food Science and Technology at University of Antananarivo in October, 2012.

Professional Memberships:
American Society for Nutrition (ASN).
Mikaroka ho an'ny fanjariantsakafo eto Madagasikara (MIKASA), national platform for nutrition researcher in Madagascar.