ORIGINAL ARTICLE

Determinants of stunting in children under 5 years in Madagascar

Hasina Rakotomanana | Gail E. Gates | Deana Hildebrand | Barbara J. Stoecker

Department of Nutritional Sciences, Oklahoma State University, Stillwater, Oklahoma, USA

Correspondence

Hasina Rakotomanana, Department of Nutritional Sciences, Oklahoma State University, Stillwater, OK 74074, USA.
Email: hasina.rakotomanana@okstate.edu

Abstract

Madagascar is among countries where the prevalence of stunting is dramatically high in under 5 years old children. This study investigated the determinants of child stunting based on the UNICEF framework on the causes of malnutrition. A cutoff at 24 months was used to separate the child population into two groups. By using the latest Demographic and Health Survey (2009), logistic regressions were performed to determine the variables associated with stunting. In 2009, 40.1% of the 1,863 children aged 0–23 months and 53.9% of the 2,911 children aged 24–59 months were stunted contributing to the 48.5% overall stunting prevalence in the sample. Girls were less likely to be stunted (adjusted odds ratio with confidence interval [AOR] = 0.69 [0.55–0.88] and 0.84 [0.72–0.97], $p < 0.01$) than boys; the risk of stunting increased with age. Regarding underlying predictors, increased maternal height was associated with lower odds of stunting in both age groups (AOR = 0.75 [0.68–0.83] and 0.69 [0.61–0.77], $p < 0.001$). Children living in households using iodized salt (>15 ppm) had lower risk of stunting in the younger group (AOR = 0.76 [0.61–0.94], $p < 0.05$). Children living in urban areas were less likely to be stunted in both age groups (AOR = 0.67 [0.51–0.88] and 0.73 [0.59–0.90] respectively, $p < 0.01$). Region of residence was also a significant basic factor for stunting. This study contributes to the understanding of the determinants of child stunting in Madagascar. The results confirmed the need for specific interventions for each of the two age groups.

KEYWORDS

child nutrition, international child health nutrition, stunting, undernutrition, UNICEF framework

1 | INTRODUCTION

With an estimated 158.6 million children affected in 2014 (WHO, 2015a), stunting is a major public health issue especially for developing countries located in Sub-Saharan Africa and Southeast Asia. The World Health Organization (WHO) reported that a total of 49.2% of children were chronically malnourished in Madagascar in 2014 placing the country among those with the highest prevalence of stunting in the world (WHO, 2015b).

Stunting, a result of chronic malnutrition, leads to short and long term negative consequences if not addressed at a young age. Short-term negative outcomes include greater susceptibility to various infections such as diarrhea and pneumonia due to a weaker immune system (Prendergast & Humphrey, 2014). Stunted children do not achieve their full developmental potential leading to poorer cognitive performance and educational achievement compared to their well-nourished counterparts. Memory and locomotor skills can be altered as well

(Georgieff, 2007). Negative associations have been found in Brazil and Guatemala between stunting and both years of schooling and salary as adults (Black et al., 2008; Dewey & Begum, 2011). Because of its intergenerational effect, stunting promotes the continuation of the cycle of poverty: stunted mothers are more likely to give birth to stunted children who will contribute less to their country's development (Prendergast & Humphrey, 2014).

Based on the UNICEF framework, there are three main categories of determinants of childhood malnutrition: the immediate causes, the underlying causes, and the basic causes (Black et al., 2013; UNICEF, 1998). Immediate or biological risk factors include the sex (Chirande et al., 2015; Linnemayr, Alderman, & Ka, 2008; Pongou, Ezzati, & Salomon, 2006), age (Blaney, Beaudry, & Latham, 2009; Bomela, 2009; Chirande et al., 2015), and birthweight of the child (Aheto, Keegan, Taylor, & Diggle, 2015; Pongou et al., 2006). A growing body of literature confirms that household factors such as family wealth (Rannan-Eliya et al., 2013), sanitation (Pongou et al., 2006), and

household size (Linnemayr et al., 2008) are among the underlying causes of malnutrition. Furthermore, maternal characteristics such as education (Linnemayr et al., 2008; Pongou et al., 2006), maternal stature (Gewa & Yandell, 2012), body mass index (Chirande et al., 2015), maternal access to health care (Blaney et al., 2009; Egata, Berhane, & Worku, 2014), and maternal age at first birth (Chirande et al., 2015) are strong determinants of stunting. Poverty, lack of capital, and political instability are among basic causes of malnutrition. Area of residence is also a determinant of stunting as rural children are more affected (Beiersmann et al., 2013). Another strong basic determinant is the geographical location (Pongou et al., 2006).

Lately, numerous nutrition interventions targeting the improvement of children's nutrition have been implemented. The Maternal and Child Nutrition Group showed that the promotion of proper complementary feeding along with other supportive strategies including educational groups and food provision were the most effective interventions to reduce stunting in children before 36 months of age (Bhutta et al., 2008). If coverage with feeding interventions combined with supportive activities were to be 99%, they predicted reductions of 19% in the prevalence of stunting in infants at 12 months and 17.2% at 24 months. There is also a focus on the preventative approach to stunting during the first 1,000 days as sufficient evidence supports that fetal growth, birthweight, and height-for-age at birth are associated with height trajectory during childhood (Khara & Dolan, 2014). However, for any intervention to be successful, it should be designed and tailored to fit the local context of the country so it can reach the most vulnerable segments of the population.

Despite being one of the 20 countries with the highest burden of malnutrition (Black et al., 2008), there is to our knowledge, very limited research regarding nutrition in Madagascar. One of the few published studies about nutrition in Madagascar was carried out by Asgary, Liu, Naderi, Grigoryan, and Malachovsky (2015) in a commune in the northern part of the country. They found a relatively high stunting prevalence (36.2%) and concluded that inadequate access to food as well as lack of nutrition knowledge by the mothers were barriers to adequate nutrition in children under 5 years. Our study used nationwide data to analyze the key factors that influence stunting in Madagascar. Knowing these factors and confirming them in future studies will be a valuable tool to help policy decision-making and to assist in more specific targeting of actions to overcome child undernutrition.

2 | METHODS

Data from the most recent Demographic and Health Survey (DHS) done for Madagascar from November 2008 to August 2009 were used. A total of 17,375 participating women aged 15 to 49 years old (INSTAT & ICF Macro, 2010) were interviewed. From the total participants, data from 4,881 women with children under 5 years created the child database. After removing children with missing values, analyses were conducted on 4,774 observations.

The 2006 WHO growth standards (WHO, 2006b) were used by the DHS group to assess height-for-age of the children with a cutoff of <-2 length/height-for-age z-score (LAZ/HAZ) to define stunting (WHO, 2006c). Variables for analysis were selected based on the literature (Chirande et al., 2015; Gewa & Yandell, 2012) and their availability in the dataset. Plausible explanatory variables were analyzed by the three categories based on the UNICEF framework: immediate, underlying, and basic determinants.

Analyses were done within two groups: 0–23 months and 24–59 months, as recommended by the WHO for continued breastfeeding (Dewey, 2002) and as suggested by previous studies (Rannan-Eliya et al., 2013). Bivariate logistic regressions were performed on each variable to determine association with LAZ/HAZ. Variables that reached a p value of <0.1 were grouped into the three factors described by UNICEF (immediate, underlying, and basic). Multivariate logistic regression models were developed for each set of factors comprising the significant variables. No weighting methods were used in any of the multivariate models. Statistical analyses were computed on SAS, v. 9.4 (SAS Institute, Cary, NC, USA) and a significance level of 5% was chosen for the final models.

3 | RESULTS

3.1 | Sociodemographic characteristics of the study population

The characteristics of the population in the two age groups (0–23 months and 24–59 months) were very similar (Table 1). The percentage of boys and girls did not differ significantly in either group. Almost half of the households were in the poorer and poorest wealth categories. The great majority ($>81\%$) of the households lived in rural areas. A total of 28.6% of mothers in the younger group and 27.9%

Key messages

- The prevalence of stunting in children under five years was extremely high (48.5%) in Madagascar in 2009.
- Determinants of stunting were different in the 0–23 months and 24–59 months age groups.
- Being male, older and anemic were identified as immediate factors associated with increased risk of stunting while increased maternal height and use of iodized salt were associated with lower risks of stunting.
- The basic factors for stunting were area and region of residence.
- Having representative nationwide data is of particular importance in national planning and in the design and targeting of effective nutrition programs.

TABLE 1 Socio-demographic characteristics of the children under 5 years of age, Madagascar 2009 (*n* = 4,774)

Age groups Variables	0–23 months		24–59 months	
	Frequency	Percentage	Frequency	Percentage
Sex				
Male	924	49.6	1480	50.8
Female	939	50.4	1431	49.2
Wealth index quintile				
Poorest	551	29.6	822	28.2
Poorer	373	20.0	632	21.7
Average	341	18.3	505	17.3
Richer	300	16.1	488	16.8
Richest	298	16.0	464	15.9
Area of residence				
Urban	332	17.8	532	18.3
Rural	1531	82.2	2379	81.7
Highest maternal education level				
No education	553	28.6	813	27.9
Primary	926	49.7	1512	51.9
Secondary	371	19.9	558	19.2
Higher	33	1.8	28	1.0
Drinking water source				
Unimproved ^a	851	46.6	1374	47.6
Improved ^b	913	50.0	1420	49.2
Piped water	62	3.4	90	3.1
Missing	37		27	
Toilets facility				
No toilet	1055	57.5	1598	55.1
Latrines (bucket, hanging, pit)	705	38.0	1204	41.5
Flush toilet	76	4.1	97	3.35
Missing	27		12	
Had diarrhea recently				
No	1606	86.2	2757	94.9
Last 2 weeks	257	13.8	147	5.1

^aUnimproved source of water: surface water, spring water, river, and rainwater.

^bImproved source of water: public tap, tube wells, and dug wells.

in the older group had no formal education. Moreover, the majority of the mothers who had gone to school attended only primary school.

A substantial proportion of the households were facing sanitation problems: less than 4% received their drinking water from protected and safe sources such as public taps or tube wells. Moreover, more than half of the households in each age group did not have toilet facilities. There were more children in the younger group who had diarrhea (13.8%) the two weeks prior to the survey compared to the older age group (5.1%).

A total of 48.4% of the children under five in the sample were stunted in 2009 (WHO, 2006a). Stunting was more prevalent in the older group (53.8% vs. 40.1%) than among younger children. The highest prevalence of stunting was observed in the regions Amoron'i Mania (66.3% for the younger group and 74.3% for older group) and Matsiatra Ambony (52.7% for the 0–23 months and 72.7% for the 24–59 months groups). Lower prevalence was calculated for the Betsiboka region (14.9% for the younger group and 23.6% for the older group; Figure 1).

3.2 | Multivariate analyses

3.2.1 | Immediate factors of stunting

In the younger children, sex, anemia severity and child age were associated with stunting (Table 2). Girls younger than 24 months were less likely to be stunted than boys of similar age. The risk of stunting increased with age. In the older group, girls were also less likely (AOR = 0.85 [0.75–0.98]) to be stunted. Severely (AOR = 4.06 [1.54–10.73]) and moderately anemic (AOR = 1.72 [1.31–2.27]) children were more likely to be stunted in the younger group. Children in the older group with moderate and mild anemia were at higher risk of being stunted (AOR = 1.76 [1.40–2.19]) and 1.25 (1.05–1.48) than those with normal hemoglobin concentrations. Only 13 children were severely anemic in the 24–59 months group, and severe anemia was not significantly associated with stunting. Also, full immunization coverage (BCG, DPT, hepatitis B, and polio) was associated with a lower risk of stunting.

FIGURE 1 Total prevalence of stunting by region

TABLE 2 Immediate factors of stunting in children under 5 years old, Madagascar 2009

Age group Variables	n (%)	0–23 months (n = 1171)		n (%)	24–59 months (n = 2749)	
		AOR (95% CI)	p value		AOR (95% CI)	p value
Sex of the child			0.002			0.021
Male	924 (49.6)	1		1480 (50.8)	1	
Female	939 (50.4)	0.73 (0.58–0.91)**		1431 (49.2)	0.85 (0.75–0.98)*	
Age of child in months	—	1.07 (1.05–1.09)***	< 0.001		1.01 (1.00–1.02)***	<0.001
Anemia level			< 0.001			<0.001
Not anemic	22 (1.6)	1		13 (1.6)	1	
Mild	398 (30.1)	1.19 (0.90–1.56)		425 (15.1)	1.25 (1.05–1.48)*	
Moderate	418 (31.6)	1.72 (1.31–2.27)***		810 (28.8)	1.76 (1.40–2.19)***	
Severe	484 (36.6)	4.06 (1.54–10.73)**		1564 (55.6)	2.29 (0.70–7.53)	
Immunization coverage ^a						0.035
Incomplete	—	Not tested	—	1845 (63.4)	1	
Complete				1064 (36.6)	0.85 (0.72–0.99)*	

AOR = adjusted odds ratios; CI = confidence interval; ns = not significant in bivariate analysis, thus not included in the multiple regression model.

^aImmunization coverage: Complete if the child received BCG, DPT, hepatitis B, and polio vaccines.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

3.2.2 | Underlying factors of stunting

The risk of stunting was lower as maternal HAZ increased in both age groups (Table 3). Children in the 0–23 months group who were still

being breastfed had lower risk of stunting. Also in the younger group, children living in households using iodized salt (concentration > 15 ppm) were less likely to be stunted compared to those using salt with 0–7 ppm iodine concentrations.

TABLE 3 Underlying factors (maternal and household) of stunting in children under 5 years old

Age group Variables (Maternal)	n (%)	0–23 months		n (%)	24–59 months	
		AOR (95% CI)	p value		AOR (95% CI)	p value
		n = 1731			n = 1644	
Maternal HAZ	—	0.75 (0.68–0.83)***	<0.001	—	0.68 (0.61–0.76)***	<0.001
Currently breastfeeding			0.004			
No	220 (11.8)	1		1616 (55.1)	Not tested	—
Yes	1643 (88.2)	0.65 (0.49–0.88)**		1295 (44.5)		
Land where mother works						<0.001
Own land	845 (63.9)			1482 (70.6)	1	
Extended family's land	349 (26.4)	ns	ns	406 (19.3)	1.63 (1.24–2.13)***	
Someone else's or rented	129 (9.8)			212 (11.1)	0.76 (0.54–1.05)	
Number of living children	—	ns	ns		1.10 (1.05–1.15)***	<0.001
Birthweight as perceived by the mothers						0.008
Larger than average	601 (32.9)			948 (33.1)	1.15 (0.92–1.44)	
Average	493 (47.1)	ns	ns	1414 (49.3)	1	
Smaller	365 (20.0)			503 (17.5)	1.56 (1.17–2.06)**	
Variables (Household)		n = 1739			n = 1146	
Wealth index						<0.001
Poorest	551 (29.6)			822 (28.2)	0.88 (0.24–3.13)	
Poorer	373 (20.0)			632 (21.7)	2.47 (1.74–3.52)***	
Average	341 (18.3)	—	— ^a	505 (17.3)	2.61 (1.89–3.62)***	
Richer	300 (16.1)			488 (16.8)	1.99 (1.48–2.69)***	
Richest	298 (16.0)			464 (15.9)	1	
Number of household members	—	ns	ns	—	1.06 (1.00–1.12)*	0.020
Salt iodine test						
0–7 ppm	683 (39.3)	1		1017 (36.8)		
8–15 ppm	335 (19.2)	0.92 (0.70–1.20)	0.038	549 (19.9)	—	— ^a
>15 ppm	721 (41.4)	0.76 (0.61–0.94)*		1198 (43.3)		
Toilets facility shared						<0.001
Yes	527 (67.5)	ns	ns	850 (65.4)	1	
No	254 (32.5)			449 (34.6)	0.61 (0.47–0.78)***	

AOR = adjusted odds ratios; CI = confidence interval; ns = not significant in bivariate analysis, thus not included in the multivariate model.

^aVariable included in the model but was not significant after multiple regression analysis.

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Children whose mothers were working on extended family's land were more likely to be stunted than children whose mothers were working on their own land. Children perceived by mothers as smaller than average at birth were also more likely to be stunted compared to those seen as having an average birthweight. In the 24–59 months group, the chances of being stunted increased with the number of household members. Not sharing toilet facility was associated with decreased odds of being stunted. Finally, still in the older group, decreased household wealth was associated with higher odds of stunting in most of wealth categories. But there was no significant difference between the richest and the poorest households regarding the odds of stunting.

3.2.3 | Basic factors of stunting

Both region and area of residence were significant basic factors predicting under five stunting (Table 4). Children living in the urban areas were less likely to be stunted in both age groups. Children living

in the region Amoron'i Mania were more than twice as likely to be stunted compared to the children living in the capitol city region Analamanga, regardless of the age group. In contrast, children living in the regions Betsiboka and Melaky were much less likely to be stunted compared to those living in Analamanga.

4 | DISCUSSION

Our results demonstrate that childhood stunting is a public health challenge in Madagascar as almost half of the children under 5 years old (48.5%) were affected in 2009. The situation has hardly changed for more than half a decade because the WHO reported a prevalence of 49% in 2014 for childhood stunting in 2015.

4.1 | Immediate factors

The key individual factors associated with stunting appeared to be sex, age of the child, and the anemia level for both age groups. Several

TABLE 4 Basic factors of stunting in children under 5 years old, Madagascar 2009

Age group Variables	0–23 months n = 1863 AOR (95% CI)	24–59 months n = 2911 AOR (95% CI)
Area of residence	0.001	0.004
Rural	1	1
Urban	0.67 (0.51–0.88)**	0.73 (0.59–0.90)**
Region of residence	<0.001	<0.001
Analamanga ^a	1	1
Alaotra Mangoro	1.06 (0.60–1.89)	1.38 (0.88–2.17)
Amoron'i Mania	2.45 (1.44–4.16)**	2.34 (1.51–3.64)**
Analanjirifo	0.89 (0.46–1.72)	1.26 (0.78–2.03)
Androy	1.07 (0.62–1.84)	1.30 (0.84–2.02)
Anosy	0.59 (0.32–1.09)	1.75 (1.10–2.79)*
Atsimo Andrefana	0.57 (0.32–0.99)*	0.91 (0.58–1.41)
Atsimo Atsinanana	0.67 (0.39–1.14)	0.85 (0.57–1.28)
Atsinanana	1.00 (0.54–1.86)	1.13 (0.74–1.34)
Betsiboka	0.22 (0.11–0.43)**	0.25 (0.16–0.41)**
Boeny	1.19 (0.69–2.07)	0.59 (0.37–0.94)*
Bongolava	0.69 (0.34–1.44)	0.93 (0.54–1.60)
Diana	1.21 (0.66–2.21)	0.57 (0.33–0.96)*
Ihorombe	0.84 (0.50–1.41)	1.04 (0.69–1.55)
Itasy	0.53 (0.29–0.96)*	1.08 (0.71–1.65)
Matsiatra Ambony	1.44 (0.88–2.36)	2.26 (1.48–3.45)**
Melaky	0.28 (0.13–0.60)*	0.42 (0.20–0.66)**
Menabe	0.97 (0.53–1.77)	0.71 (0.43–1.15)
Sava	0.66 (0.33–1.32)	0.65 (0.39–1.06)
Sofia	0.41 (0.23–0.73)*	0.66 (0.43–1.00)
Vakinankaratra	1.54 (0.89–2.66)	1.25 (0.81–1.91)
Vatovavy Fitovinany	0.68 (0.39–1.19)	1.00 (0.66–1.52)

AOR = adjusted odds ratios; CI = confidence interval.

^aCapitol region.**p* < 0.05. ***p* < 0.001.

studies done in Sub-Saharan Africa found that risk of stunting increases with age (Chirande et al., 2015; Gewa & Yandell, 2012; Pongou et al., 2006). Stunting can begin *in utero* and a study using data from 54 countries from the WHO Global Database on Child Growth and Malnutrition confirmed the mean LAZ of infants drops dramatically until 24 months, indicating that odds of being stunted are higher as the infant grows older during this time frame (De Onis & Branca, 2016; Victora, de Onis, Hallal, Blossner, & Shrimpton, 2010). Anemia, particularly iron-deficiency anemia has been shown to alter children growth through various pathways involving energy metabolism and myelination (Soliman, De Sanctis, & Karla, 2014).

In both age groups, sex was a significant determinant as boys were more likely to be stunted compared to girls in both age groups, which is in accordance with findings from other sub-Saharan countries (Chirande et al., 2015; Linnemayr et al., 2008; Pongou et al., 2006). A meta-analysis using DHS data from 16 African countries concluded that boys were consistently at higher risk of stunting than girls in 10 of the countries with an OR = 1.16 (Wamani, Astrom, Peterson, Tumwine, & Tylleskar, 2007). Comparison of the normal height-for-age growth curves (50th percentiles) between boys and girls showed that

boys are consistently taller than girls suggesting more rapid growth and higher nutritional needs (WHO, 2006a). Given the same amount of food, boys may be more likely to be stunted than girls.

Tested in the older group only, because not all younger children had reached recommended age for certain immunizations, complete immunization coverage was associated with lower risk of stunting. A study in Indonesia concluded that complete immunization was associated with lower morbidity and lower prevalence of stunting in children aged 12–59 months (Semba et al., 2007). Given the sanitary conditions in Madagascar, where 46.6% of the households drank from unprotected water sources and only 3.6% had improved toilet facilities, having all required immunizations could be critical in the prevention of infectious diseases that affect not only nutritional status but also general health. As suggested by Gewa and Yandell (2012), mothers of the children with complete immunization coverage also may have access to health care and more contact with health professionals leading to better nutrition and health knowledge and thus better nutritional status in children.

4.2 | Underlying factors

Maternal height was a significant underlying factor for stunting in both age groups. Maternal stature has been shown as a strong determinant of child undernutrition in various studies (Chirande et al., 2015; Gewa & Yandell, 2012; Rannan-Eliya et al., 2013). Using data from developing countries, Victora et al. (2008) confirmed the consistent positive association between maternal height and infants' HAZ/LAZ as well as birthweight. They found significant association between birthweight of the children and their grandmother's height, suggesting that the intergenerational effects of undernutrition last at least for three generations (Victora et al., 2008).

Black et al. (2008) pointed out the association between maternal short stature and maternal BMI and child undernutrition. We also found that children whose mothers had low BMI (<18.5) were more likely to be stunted (data not shown); however, the BMI variable was not included in the multivariate models because of correlation with maternal height. Low BMI in mothers may be due to overall food insecurity in the household. Gewa and Yandell (2012) argued that an environment lacking in adequate nutritious food sources would affect children and parents in a similar way, resulting in poor nutritional status for both. A study investigating seasonal food poverty reported that more than two thirds of the Malagasy population had an average intake below 2,133 calories. Intakes can drop as low as 1,794 calories per capita within poor households during the lean season suggesting overall food insecurity (Dostie, Haggblade, & Randriamamonjy, 2002).

The lower risk of stunting in the younger group if the mother is currently breastfeeding may be explained by the protective effects of breastfeeding on growth and development during the first 2 years of life (Dewey, 2002). The same variable was omitted in the older group model because we could not determine if the mother was currently breastfeeding a child in the older group or if the child being breastfed was in the younger group.

Not using iodized salt was significantly associated with stunting in the 0–23 months group as the odds ratio decreased with an increased concentration of iodine in domestic salt (OR = 0.76 with a

concentration more than 15 ppm of iodine compared to 0–7 ppm). In fact, iodine has been shown to play a role in growth and development through the thyroid hormones (Farebrother et al., 2015; Zimmermann, 2012). The Comprehensive Food and Nutrition Security and Vulnerability Analysis conducted in the rural areas of Madagascar in 2010 showed that only 28.1% of the infants aged 6–12 months, 35.5% of infants 12–18 months, and 36.5% of the infants aged 18–24 months were given flesh foods potentially rich in iodine such as fish and other seafoods. Even lower proportions were given eggs, another potential source of dietary iodine (WFP & UNICEF, 2011). After the first 6 months, most of the breastfed children would still rely primarily on the iodine content in breast milk because of the low consumption of iodine-rich foods and because they consume only small amounts of the family food. Also, 19.9% of the households did not have the recommended concentration of iodine in their salt (>15 ppm). Thus, because infants still rely on breast milk for their iodine needs, they are at higher risk of stunting if the lactating mothers do not have sufficient iodine intake (WHO Secretariat et al., 2007). Using iodized salt may also reflect better nutrition knowledge in mothers leading to better nutrition outcomes in children.

Mothers who work on extended family lands have children with higher risk of being stunted in the 24–59 months group compared to mothers who work on their own land. Maternal working status may be a determinant for child growth, especially if they work in agriculture, because of the limited time allocated to childcare and nutrition as they spend all day away from their children. Households who have to work on family's land have to split the agricultural products reducing considerably the food supply compared to those who work on their own land.

Children perceived by the mothers as small during delivery were more likely to be stunted. They may in fact have been low birthweight, which will put them at a higher risk of stunting. Channon (2011) reported that mothers' perception of infant size is a suitable proxy for birthweight regardless of the country.

Numerous studies have demonstrated the importance of household wealth in children's nutritional status (Chirande et al., 2015; Egata et al., 2014; Linnemayr et al., 2008; Pongou et al., 2006). Higher family wealth usually means that more resources can be distributed to nutrition and health care in general suggesting lesser risks of undernutrition in children (Smith, Ruel, & Ndiaye, 2005). However, although the odds of stunting were reduced in the second through the fourth quintile compared to the richest, the poorest households were not significantly different from the highest quintile. The poorest household may have been eating other sources of food that could influence children's nutritional status that were not being captured in the questions asked by the DHS. For example, Ramaroson Rakotosamimanana, Valentin, and Arvisenet (2015) reported that eating *Moringa oleifera* leaves is fairly common in children in the northern part of the country compared to children living in the capital. Because *Moringa* is a good source of protein, its nutritional consumption is likely to benefit the children's growth. Our results confirm that household wealth alone does not explain stunting odds in the poorest households.

Reduced risk for stunting was associated with not sharing toilet facilities with other households. Having poor sanitation and more generally poor WASH indicators have been linked to child undernutrition

through direct biological mechanisms involving diarrhea, parasitic infection, or tropical enteropathy (Cumming & Cairncross, 2016). Plus, from our analysis, children who lived in households that had shared toilets were more likely to have had diarrhea within the two weeks prior to the survey (data not shown).

4.3 | Basic factors

The area and region of residence were strong predictors of child stunting for both age groups. Urban children were less likely to be stunted as confirmed by a study from 36 developing countries (Smith et al., 2005). The authors suggested that children living in urban areas have better socioeconomic conditions that promote better nutritional status than their rural counterparts. However, the positive effects of living in urban areas are cumulative and children presumably would be exposed to the advantages for their lifetime. For instance, they may be born to well-nourished mothers, already reducing considerably the risk of stunting; they are also more likely to receive better complementary food and be provided better health care. Our analyses revealed that the mean diet diversity score was higher in children living in urban areas (2.42) than in rural areas (1.36).

The differences in the odds of stunting in various regions of Madagascar may be explained by the availability of the resources for food as well as the work opportunities. The Analamanga region was chosen as a reference because it encloses the capital city. The Sofia, Melaky, and Betsiboka regions are located on the coast and/or near fishing areas, suggesting that households can generate money and have healthier food sources. Additionally, these three regions have several touristic sites providing another source of income for households working on these sites. Such factors may explain why children living in these regions have lower risks of being stunted compared to children living in the Analamanga region. On the other hand, children living in the Amoron'i Mania region were at increased risk of stunting compared to children living in the capitol region. Landlocked regions do not necessarily have access to diverse foods, especially during the lean season. A substantial proportion of the households in these regions were below the second wealth index quintile (36.4% for Matsiatra Ambony and 50.7% for Amoron'i Mania, data not shown). However, household wealth alone does not explain the higher risk of stunting in these regions because other regions such as Atsimo Atsinanana have dramatically higher proportions of poor households (71.4%) yet the risk of stunting is not significantly different compared to Analamanga.

4.4 | Implications for the Malagasy national nutrition plan

The *Plan National d'Action pour la Nutrition* (PNAN II 2012–2015), the most recent national nutrition plan of Madagascar, has five main focus points including preventing and managing malnutrition as well as reducing malnutrition risks in vulnerable groups in case of natural disasters (Repoblikan'i Madagasikara, 2012). The proposed interventions are focused on the promotion of community programs, micronutrient supplementation and fortification, deworming, and nutrition education among adolescents, school-aged children, pregnant women, and children under 5 years of age. Several interventions mentioned in

the PNAN II have successfully reduced stunting in other developing countries. Preliminary studies including a landscape nutrition analysis by international experts from UNICEF and WHO as well as an evaluation of the former National Nutrition Plan were done prior to the elaboration of the PNAN II. However, specific data on determinants of child undernutrition in Madagascar are scarce. Morris, Cogill, and Uauy (2008) argued that the rarity of strong evidence-based data and the lack of relevant national program evaluations are one of the main reasons why nutrition interventions are having low success.

One of the main findings of this study is the disparity between the 22 regions of Madagascar in terms of stunting prevalence and the odds for children under five to be stunted. Having individual regional nutritional plans could be a more effective way to tackle the problem as argued by Bryce, Coitinho, Darnton-Hill, Pelletier, and Pinstrup-Andersen (2008). Goals and objectives are written at a national level in the PNAN II; however, some regions, for instance, Amoron'i Mania, may require more interventions and more specific actions than others because of the very high prevalence of stunting. Moreover, resources available and cultural context are different for each region, suggesting that diverse approaches may be needed. The present study highlights the importance of designing more specific and tailored interventions at a subnational level. Further analyses of data as new surveys are completed should be included to advise on the determinants of child stunting in each region.

The PNAN II includes a wide variety of nutrition education programs targeted to mothers and women of reproductive age about healthy nutrition and complementary feeding. Education strategies alone, however, are less likely to have a positive impact on child undernutrition especially in food insecure populations (Bhutta et al., 2008). The total cereal needs for the country have been consistently higher than the amount of cereal available from 2004 to 2010 suggesting a general caloric deficit (WFP & UNICEF, 2011). Additionally, Liu et al. (2008) predicted that Madagascar would remain one of the hotspots of food insecurity for the next decades. According to the population growth and the climate change, they reported that Madagascar would have less caloric intake per capita and a decrease in the capacity for importing food leading to additional undernutrition problems. Providing solutions to food insecurity is critical along with planning nutrition education sessions. Because more than 80% of the population making their living from agriculture, reinforcing this sector would not only give better food sources but also would improve household income. Minten and Barrett (2007) suggested that enhancing the yields of staple crops such as rice and cassava through the adoption of improved agricultural technologies would be associated with better economic conditions for the poorest households in Madagascar. They also concluded that cash crop production such as vanilla and cloves was associated with improved welfare indicators.

Another point to be addressed in the fight against malnutrition in Madagascar is investment in capacity building and training of local human capital. As Morris et al. (2008) reported, the lack of skilled personnel and nutrition specialists in developing countries is an obstacle for the success of nutrition actions. The results of the Landscape Analysis conducted in the 36 countries with the highest burden of undernutrition, including Madagascar, showed the inadequacy of nutrition specialists in all of the countries. Postgraduate degrees in nutrition

are limited, and the existing ones tend to focus more on disease control (Trübsswasser, Nishida, Engesveen, & Coulibaly-Zerbo, 2012). There is an urgent need to design and implement nutrition curriculum throughout the teaching and research institutions in the country. Advanced training in nutrition should bring not only necessary knowledge and skills but also motivation and ability for malnutrition-related jobs and activities (Morris et al., 2008).

Overall, our results confirmed the multifactorial aspects of stunting, as several of the risk factors are not directly related to child nutrition. Promoting and implementing nutrition-sensitive interventions, particularly in agriculture, education, and health should be seriously considered in national planning. One of the main strategic points of the PNAN II is to reduce food insecurity by diversifying agricultural activities. The PNAN II includes programs that promote the production of short cycle livestock and the culture of vegetables through dissemination of improved agriculture, improving access to micronutrients and animal products. Such nutrition-sensitive activities in different sectors would be helpful in the effort to reduce malnutrition. For instance, the Ethiopian Nutrition Plan aimed to strengthen nutrition related interventions in agriculture, education, sanitation, and industry. Their initiatives in the education sector include promoting key nutrition actions in schools, such as gardening and nutrition clubs, as well as capacity building of teachers regarding nutrition and food security (Government of the Federal Democratic Republic of Ethiopia, 2013). The next National Nutrition Plan for Madagascar should be multisectorial as well and should be part of a broader action plan including agricultural, economic, health, and education-related considerations.

Our study looked at the determinants of child stunting according to the UNICEF framework on the causes of malnutrition using nationwide data. By doing so, we explored the association between several explanatory variables and child stunting. The DHS sampling frame is widely known as representative and fairly captures the global situation within a country. However, there are some limitations in using survey data. For instance, recall bias can occur especially when asking about child nutrition and child feeding practices. Also, child weight was omitted from this particular dataset because of the lack of precision during measurements. Thus, other indicators of undernutrition and their determinants could not be calculated. Finally, the way the breastfeeding data were collected was confusing. Questions were asked, both on the length of breastfeeding in months and on the current breastfeeding status, for all children under five in the household. Especially when considering children above 24 months, the answer to a question about current breastfeeding status of the mother could be misleading because she could be breastfeeding but the index child might be in the younger age group rather than in the 24–59 month group.

5 | CONCLUSIONS

Our results confirmed the very high stunting rate of under five children in Madagascar in 2009. Stunting prevalence and risks varied across different regions of Madagascar. The determinants of stunting were different in young children (0–23 months) and in children aged

24–59 months, leading to the conclusion that nutrition interventions should be different for each age group. Because underlying and basic factors greatly affect children's nutritional status, consideration of these factors is required when designing programs and nutrition actions targeting the reduction of stunting. Malnutrition is a multifactorial problem, so sustainable solutions should include multiple sectors mainly agriculture, education, and public health as well as increased household income.

ACKNOWLEDGMENTS

The authors wish to thank the US Department of State through the Fulbright Program for Foreign Students for funding HR's graduate studies. The authors also gratefully acknowledge DHS Program and ICF Macro for allowing access to the data. We like to thank the Department of Nutritional Sciences in the College of Human Sciences at Oklahoma State University.

SOURCE OF FUNDING

None.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

HR and BJS were involved in the design of the study and the data analysis. HR, BJS, GEG, DH prepared and revised the manuscript.

REFERENCES

Aheto, J. M., Keegan, T. J., Taylor, B. M., & Diggle, P. J. (2015). Childhood malnutrition and its determinants among under-five children in Ghana. *Paediatric and Perinatal Epidemiology*, 29(6), 552–561. doi:10.1111/ppe.12222

Asgary, R., Liu, M., Naderi, R., Grigoryan, Z., & Malachovsky, M. (2015). Malnutrition prevalence and nutrition barriers in children under 5 years: A mixed methods study in Madagascar. *International Health*, 7(6), 426–432. doi:10.1093/inthealth/ihv016

Beiersmann, C., Bermejo Lorenzo, J., Bountogo, M., Tiendrebeogo, J., Gabrys, S., Ye, M., ... Müller, O. (2013). Malnutrition determinants in young children from Burkina Faso. *Journal of Tropical Pediatrics*, 59(5), 372–379. doi:10.1093/tropej/fmt037

Bhutta, Z. A., Ahmed, T., Black, R. E., Cousens, S., Dewey, K., Giugliani, E., ... the Maternal and Child Undernutrition Study Group (2008). What works? Interventions for maternal and child undernutrition and survival. *Lancet*, 371(9610), 417–440. doi:10.1016/s0140-6736(07)61693-6

Black, R. E., Allen, L. H., Bhutta, Z. A., Caulfield, L. E., de Onis, M., Ezzati, M., ... Maternal and Child Undernutrition Study Group. (2008). Maternal and child undernutrition: Global and regional exposures and health consequences. *Lancet*, 371(9608), 243–260. doi:10.1016/s0140-6736(07)61690-0

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., de Onis, M., ... Maternal and Child Nutrition Study Group. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet*, 382(9890), 427–451. doi:10.1016/s0140-6736(13)60937-x

Blaney, S., Beaudry, M., & Latham, M. (2009). Determinants of undernutrition in rural communities of a protected area in Gabon. *Public Health Nutrition*, 12(10), 1711–1725. doi:10.1017/s1368980008004035

Bomela, N. J. (2009). Social, economic, health and environmental determinants of child nutritional status in three Central Asian Republics. *Public Health Nutrition*, 12(10), 1871–1877. doi:10.1017/s1368980009004790

Bryce, J., Coitinho, D., Darnton-Hill, I., Pelletier, D., & Pinstrup-Andersen, P. (2008). Maternal and child undernutrition: Effective action at national level. *Lancet*, 371(9611), 510–526. doi:10.1016/s0140-6736(07)61694-8

Channon, A. A. (2011). Can mothers judge the size of their newborn? Assessing the determinants of a mother's perception of a baby's size at birth. *Journal of Biosocial Science*, 43(5), 555–573. doi:10.1017/s0021932011000198

Chirande, L., Charwe, D., Mbwana, H., Victor, R., Kimboka, S., Issaka, A. I., ... Agho, K. E. (2015). Determinants of stunting and severe stunting among under-fives in Tanzania: Evidence from the 2010 cross-sectional household survey. *BMC Pediatrics*, 15(1), 165. doi:10.1186/s12887-015-0482-9

Cumming, O., & Cairncross, S. (2016). Can water, sanitation and hygiene help eliminate stunting? Current evidence and policy implications. *Maternal & Child Nutrition*, 12(Suppl 1), 91–105. doi:10.1111/mcn.1258

De Onis, M., & Branca, F. (2016). Childhood stunting: A global perspective. *Maternal & Child Nutrition*, 12(Suppl 1), 12–26. doi:10.1111/mcn.12231

Dewey, K. G. (2002). Guiding principles for complementary feeding of the breastfed child. Retrieved from http://www.who.int/nutrition/publications/guiding_principles_compfeeding_breastfed.pdf.

Dewey, K. G., & Begum, K. (2011). Long-term consequences of stunting in early life. *Maternal & Child Nutrition*, 7(Suppl 3), 5–18. doi:10.1111/j.1740-8709.2011.00349.x

Dostie, B., Haggblade, S., & Randriamamonjy, J. (2002). Seasonal poverty in Madagascar: magnitude and solutions. *Food Policy*, 27, 493–518. doi:10.1016/S0306-9192(02)00063-5

Egata, G., Berhane, Y., & Worku, A. (2014). Predictors of acute undernutrition among children aged 6 to 36 months in east rural Ethiopia: A community based nested case–Control study. *BMC Pediatrics*, 14, 91. doi:10.1186/1471-2431-14-91

Farebrother, J., Naude, C. E., Nicol, L., Sang, Z., Yang, Z., Andersson, M., ... Zimmermann, M. B. (2015). Systematic review of the effects of iodised salt and iodine supplements on prenatal and postnatal growth: Study protocol. *BMJ Open*, 5(4) e007238. doi:10.1136/bmjopen-2014-007238

Georgieff, M. K. (2007). Nutrition and the developing brain: Nutrient priorities and measurement. *American Journal of Clinical Nutrition*, 85(2), 614s–620s.

Gewa, C. A., & Yandell, N. (2012). Undernutrition among Kenyan children: Contribution of child, maternal and household factors. *Public Health Nutrition*, 15(6), 1029–1038. doi:10.1017/s136898001100245x

Government of the Federal Democratic Republic of Ethiopia. (2013). National nutrition programme. Retrieved from http://www.unicef.org/ethiopia/National_Nutrition_Programme.pdf.

INSTAT & ICF Macro. (2010). Enquête Démographique et de Santé de Madagascar 2008–2009. Retrieved from http://pdf.usaid.gov/pdf_docs/Pnadt385.pdf.

Khara & Dolan. (2014). The relationship between wasting and stunting, policy, programming and research implications. Technical Briefing paper. Retrieved from <http://www.ennonline.net/waststuntreview2014>.

Linnemayr, S., Alderman, H., & Ka, A. (2008). Determinants of malnutrition in Senegal: individual, household, community variables, and their interaction. *Economics and Human Biology*, 6(2), 252–263. doi:10.1016/j.ehb.2008.04.003

Liu, J., Fritz, S., Van Wesenbeeck, C., Fuchs, M., Liangzhi, Y., Obersteiner, M., & Yang, H. (2008). A spatially explicit assessment of current and future hotspots of hunger in Sub-Saharan Africa in the context of global change. *Global and Planetary Change*, 64, 222–235.

- Minten, B., & Barrett, C. B. (2007). Agricultural technology, productivity, and poverty in Madagascar. *World Development*, 36(5), 797–822. doi:10.1016/j.worlddev.2007.05.004
- Morris, S. S., Cogill, B., & Uauy, R. (2008). Effective international action against undernutrition: Why has it proven so difficult and what can be done to accelerate progress? *Lancet*, 371(9612), 608–621. doi:10.1016/s0140-6736(07)61695-x
- Pongou, R., Ezzati, M., & Salomon, J. A. (2006). Household and community socioeconomic and environmental determinants of child nutritional status in Cameroon. *BMC Public Health*, 6, 98. doi:10.1186/1471-2458-6-98
- Prendergast, A. J., & Humphrey, J. H. (2014). The stunting syndrome in developing countries. *Paediatrics & International Child Health*, 34(4), 250–265. doi:10.1179/2046905514y.0000000158
- Ramaroson Rakotosamimanana, V., Valentin, D., & Arvisenet, G. (2015). How to use local resources to fight malnutrition in Madagascar? A study combining a survey and a consumer test. *Appetite*, 95, 533–543. doi:10.1016/j.appet.2015.08.011
- Rannan-Eliya, R. P., Hossain, S. M., Anuranga, C., Wickramasinghe, R., Jayatissa, R., & Abeykoon, A. T. (2013). Trends and determinants of childhood stunting and underweight in Sri Lanka. *Ceylon Medical Journal*, 58(1), 10–18. doi:10.4038/cmj.v58i1.5357
- Repoblikan'i Madagasikara. (2012). Plan d'action pour la nutrition 2012–2015. Retrieved from http://scalingupnutrition.org/wp-content/uploads/2013/02/Madagascar_PNAN-2012_2015.pdf
- Semba, R. D., de Pee, S., Berger, S. G., Martini, E., Ricks, M. O., & Bloem, M. W. (2007). Malnutrition and infectious disease morbidity among children missed by the childhood immunization program in Indonesia. *Southeast Asian Journal of Tropical Medicine and Public Health*, 38(1), 120–129.
- Smith, L. C., Ruel, M. T., & Ndiaye, A. (2005). Why is child malnutrition lower in urban than in rural areas? Evidence from 36 developing countries. *World Development*, 33(8), 1285–1305. doi:10.1016/j.worlddev.2005.03.002
- Soliman, A. T., De Sanctis, V., & Karla, S. (2014). Anemia and growth. *Indian Journal of Endocrinology and Metabolism*, 18(Suppl1), S1–S5. doi:10.4103/2230-8210.145038
- Trübswasser, U., Nishida, C., Engesveen, K., & Coulibaly-Zerbo, F. (2012). Landscape analysis-assessing countries' readiness to scale up nutrition actions in the WHO african region. *African Journal of Food, Agriculture, Nutrition and Development*, 12(4), 6260–6273.
- UNICEF. (1998). The state of the world's children 1998. Retrieved from <http://www.unicef.org/sowc/archive/ENGLISH/The%20State%20of%20the%20Worlds%20Children%201998.pdf>.
- Victora, C. G., Adair, L., Fall, C., Hallal, P. C., Martorell, R., Richter, L., & Sachdev, H. S. (2008). Maternal and child undernutrition: Consequences for adult health and human capital. *Lancet*, 371(9609), 340–357. doi:10.1016/s0140-6736(07)61692-4
- Victora, C. G., de Onis, M., Hallal, P. C., Blossner, M., & Shrimpton, R. (2010). Worldwide timing of growth faltering: Revisiting implications for interventions. *Pediatrics*, 125(3), e473–e480. doi:10.1542/peds.2009-1519
- Wamani, H., Astrom, A. N., Peterson, S., Tumwine, J. K., & Tylleskar, T. (2007). Boys are more stunted than girls in Sub-Saharan Africa: A meta-analysis of 16 demographic and health surveys. *BMC Pediatrics*, 7, 17. doi:10.1186/1471-2431-7-17
- WFP & UNICEF. (2011). Rural Madagascar comprehensive food and nutrition security and vulnerability analysis. 184. Retrieved from http://www.wfp.org/sites/default/files/MAG%202010%20CFSVA+N_Full%20report_English.pdf
- WHO. (2006a). Child growth standards: Length/height-for-age. Retrieved from http://www.who.int/childgrowth/standards/height_for_age/en/
- WHO. (2006b). Executive summary: WHO Child Growth Standards. Retrieved from http://www.who.int/childgrowth/standards/tr_summary/en/
- WHO. (2006c). WHO child growth standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development. Retrieved from http://www.who.int/childgrowth/standards/technical_report/en/
- WHO. (2015a). Global and regional trends by WHO Regions, 1990–2014 Stunting. Retrieved from <http://apps.who.int/gho/data/node.main.NUTWHOREGIONS?lang=en>
- WHO. (2015b). World health statistics. Retrieved from http://www.who.int/gho/publications/world_health_statistics/2015/en/
- WHO Secretariat, Andersson, M., de Benoist, B., Delange, F., & Zupan, J. (2007). Prevention and control of iodine deficiency in pregnant and lactating women and in children less than 2-years-old: Conclusions and recommendations of the technical consultation. *Public Health Nutrition*, 10(12A), 1606–1611. doi:10.1017/S1368980007361004
- Zimmermann, M. B. (2012). The effects of iodine deficiency in pregnancy and infancy. *Paediatric and Perinatal Epidemiology*, 26(Suppl 1), 108–117. doi:10.1111/j.1365-3016.2012.01275.x

How to cite this article: Rakotomanana H, Gates GE, Hildebrand D, Stoecker BJ. Determinants of stunting in children under 5 years in Madagascar. *Matern Child Nutr.* 2017;13:e12409. <https://doi.org/10.1111/mcn.12409>