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Factors influencing undernutrition among children under 5 years from cocoa-growing communities in Bougainville

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ABSTRACT

Half the children under the age of 5 years in Papua New Guinea (PNG) are undernourished, more than double the global average with rural areas disproportionately affected. This study examines factors associated with stunting, wasting and underweight in cocoa growers' children (<5 years) in the Autonomous Region of Bougainville (ARoB), using data from a comprehensive 2017 cross-sectional livelihoods survey. Sixteen independent predictors for stunting, wasting and underweight were selected based on the UNICEF Conceptual Framework of Determinants of Undernutrition. We used multilevel logistic mixed regression models to measure the association of the explanatory variables with stunting, wasting and underweight. At the household level, the adjusted OR (aOR) of stunting (aOR=1.71,95% CI 1.14 to 2.55) and underweight (aOR=2.11, 95% CI 1.16 to 3.82) increased significantly among children from households with unimproved toilet facilities. The aOR for underweight also increased among children from households without access to clean drinking water (aOR=1.97, 95% CI 1.19 to 3.29). Short maternal stature was significantly associated with child stunting, the odds increased as maternal height decreased (from 150 to <155 cm, aOR=1.52, 95% CI 1.02 to 2.26) (<150 cm, aOR=2.37, 95% CI 1.29 to 4.35). At the individual level, the odds of a child being underweight increased with birth order (second born, aOR=1.92, 95% CI 1.09 to 3.36; third born, aOR=6.77, 95% CI 2.00 to 22.82). Compared with children less than 6 months, children aged 6–23 months and 24–59 months had a higher odds of being stunted (aOR=3.27, 95% CI 1.57 to 6.78 and aOR=2.82, 95% CI 1.40 to 5.67) and underweight (aOR=4.83, 95% CI 1.36 to 17.24 and aOR=4.59, 95% CI 1.29 to 16.26). No variables were found to be significant for wasting. Interventions that simultaneously target key life stages for women and children and the underlying social and environmental determinants are required for sustained improvements to undernutrition.

Key questions

What is already known?

- Undernutrition increases the risk of child morbidity, mortality, poor cognitive development, chronic diseases in adults and reduced human and economic productivity.
- Papua New Guinea (PNG) has among the worst nutrition outcomes for children <5 years of age globally, and there is limited current evidence on specific drivers of undernutrition in PNG and the Autonomous Region of Bougainville (ARoB).
- Cocoa farming, PNG's third largest export and the primary livelihood for Bougainville, continues to have low productivity levels and labour shortages. Poor health and nutrition are thought to be contributing factors.

What are the new findings?

- Only study assessing factors associated with child undernutrition within the ARoB and broader islands region of PNG.
- Water and sanitation are key factors associated with undernutrition among children <5 years in Bougainville.
- Short maternal stature (<150 cm) increased the odds of a child being stunted by 2.37 times compared with the tallest maternal height group (≥155 cm).
- Children ≥6 months had a higher odds of being stunted and underweight compared with children <6 months.

What do the new findings imply?

- Improving nutrition outcomes and the livelihoods of cocoa-farming communities in Bougainville requires holistic, interdisciplinary interventions that simultaneously target critical life stages for women and children and the underlying social and environmental determinants.
- These new findings provide a necessary evidence base for developing tailored policies and interventions aimed at improving the nutrition, health, productivity and overall livelihoods of smallholder cocoa-farming families within Bougainville.

INTRODUCTION

Child undernutrition is a leading contributor to death and disability globally. It is responsible for nearly half the deaths in children less than 5 years of age,[1] with a disproportionate burden in low-and-middle-income countries (LMICs).

Undernutrition is detrimental to individuals, households and the broader community. Undernourished children have an increased risk of mortality, are more likely to suffer a childhood illness, be cognitively impaired, perform poorer in school, have lower earning potential and carry higher risks for non-communicable diseases in later life.[2] These effects of poor nutrition start in utero and span generations. Undernourished women have a higher risk of giving birth to low birthweight babies, who in turn have a higher risk of suboptimal growth and development.[3]

The WHO, in response to this evidence, set goals to reduce the number of stunted children by 40% and to maintain childhood wasting to less than 5% by 2025.[4] These goals have been further reinforced by the second Sustainable Development Goal.[5]

Determinants of undernutrition have been well documented in the literature. The UNICEF Conceptual framework for causes of malnutrition categorises these determinants into immediate (dietary intake and disease), underlying (household food security, care and feeding practices, unhealthy household environment and inadequate healthcare services) and basic causes (geographical location, lack of capital and resources).[6]

While good progress has been made in reducing the level of child undernutrition globally, progress has slowed down in the Asia-Pacific region, where over half the world's malnourished children live.[7] Papua New Guinea (PNG) has the highest prevalence (65%) for combined stunting, wasting and overweight.[8] Similar to other LMICs, undernutrition remains a greater burden in the more populous rural areas of PNG,[9] where smallholder farming continues to be the main source of livelihood. Being one of the most ethnically diverse countries in the world, the environmental conditions, cultural practices and diets vary greatly between geographical areas.[9] This heterogeneity calls for a better understanding of the context-specific drivers of poor nutrition within subpopulations.

To further this understanding, we administered a large cross-sectional household survey with cocoa-farming communities in the Autonomous Region of Bougainville (ARoB), a rural and remote island province of PNG. The ARoB endured a decade long conflict between 1988 and 1998 which decimated local health and education infrastructure. Many people today are without access to basic healthcare, clean water and sanitation—open defecation is common,[10,11] a behaviour which Spears reported could account for a large portion of the variation in child height internationally.[12]

Two-thirds of the ARoB population are smallholder cocoa farmers.[13] Cash crop farmers face a number of risks and uncertainties related to productivity such as unstable market prices, pests and diseases and the increasing threat of severe weather events associated with climate change.[14–16] In the ARoB, this has been exacerbated by sustained low levels of cocoa productivity in the years following the conflict. Efforts to improve farming practices over the years have not been fully realised. It is thought that this may be caused by poor uptake and underlying constraints within the local community.[17] While a range of factors can influence cocoa production, our research suggests that high levels of poor health and nutrition play a considerable role in the ARoB.[11,13] Similar links have been drawn by other studies involving smallholder cocoa farmers.[15,18] Persistent poor health and nutrition are major factors underpinning farmers' capacity to improve cocoa yield, sales and income. Conversely, a reduced income may limit access to nutritious foods and healthcare, leading to poorer nutrition and health.[13] Many cocoa-farming communities own livestock (61%) that share living spaces—this increases the risk of faecal–oral transmission of pathogens to humans. Repeated infections over time are associated with poor nutrition and growth of children.[19] The challenges faced by smallholder cocoa farmers are complex and multifactorial, requiring the knowledge and skills from multiple disciplines.

This study is part of a larger 6-year ACIAR funded project (HORT/094/2016) which uses a One Health approach to enhance cocoa farmer productivity and livelihoods by assessing and addressing the health of the farmer, cocoa tree and the environment. A One Health approach involves transdisciplinary teams working together to improve health outcomes for humans, animals and the environment in which they inhabit.[20] Details of this approach are outlined in a separate paper.[21]

Despite the known links between health, nutrition, labour availability and productivity being known,[22] many agriculture development programmes to date have been discipline-centric with focus on improving farming practices via technology. Without simultaneously addressing the health, nutrition and environmental needs of the farming communities, improvements in productivity will be limited.[17] Understanding the nutritional status and identifying factors associated with poor nutrition are a key component to improving livelihoods of cocoa farmers in the ARoB.

Although PNG has some of the highest rates of child undernutrition in the world, there is scarce research into the specific drivers of poor nutrition within PNG.[9,23] Geographical location, particularly rural residence, has been shown to be significantly associated with child undernutrition in PNG.[24–26] At the household level, poorer household wealth,[24,27] inadequate water supply and overcrowding,[27] lower maternal education,[27–29] poorer asset ownership of mothers[30] and lower education level of household head[24] were reported to be significant. At the individual level, Olita'a *et al* found younger maternal age, low birth weight, short birth interval and incomplete vaccination were significant factors.[27] Due to a paucity of PNG data, many of these studies used older datasets, which may not reflect the current context. To the best of our knowledge, no other study has assessed

Box 1 Principles for selecting participating villages

- ► Village must identify as a cocoa-growing community.
- ► Village must demonstrate motivation and leadership to participate in study.
- ► Villages selected must cover a geographically diverse area and include remote areas.
- ► Villages selected for the study should include those that have and have not previously received support.
- ► Study sample should complement other projects on the ground and avoid duplication.
- ► Village should have potential for farming diversification.

the multilevel factors associated with child undernutrition within the ARoB or the broader islands region of PNG. Therefore, our research aims to provide an understanding of the nutritional status and key factors associated with undernutrition among children under 5 from cocoa-growing communities in the ARoB.

METHODS

Data source and sampling method

We conducted a cross-sectional household survey across three regions of Bougainville—North, Central, South—over a 12-month period in 2017. A census of households was implemented in 33 purposively selected village assemblies (VAs), 11 from each of the three regions. A VA comprises two or more villages. A total of 2348 households were sampled from the 33 VAs. Only 24 households did not participate in the study due to respondents not being home at the time of interview, severe illness and a small number did not want to participate. Villages were purposively selected by our in-country team members using the principles detailed in box 1.

Information was captured at both household and individual levels (men ≥ 15years, women aged 15–49 years and children under 5). Anthropometric measurements were captured for women 15–49 years (approximately reproductive age) and children under the age of 5 years.

The survey used a combination of validated questionnaires (UNICEF MICS, USAID DHS, WHO World Health Survey) and comprised six modules: Household, Men (15 years+), Women (15–49years), Children (under 5years), Women's Anthropometric (15–49years) and Children's Anthropometric (under 5years). Questions were translated into Tok Pisin and piloted. Trained interviewers administered the survey using CommCare, a mobile data capture application on android tablets. CommCare enables data to be captured offline in the field and uploaded to the server at a later time when internet connectivity was available. Interviewers were also trained in performing routine anthropometric measurements. Interviews were conducted at the household in a private location, consent was obtained at the time of interview. Further details on the livelihood, survey is documented in a formal report (https://tadep-png.com/wp-content/uploads/2020/04/Report-on-the-Results-of-a-Livelihood-Survey-of-Cocoa-Farmers-in-Bougainville.pdf).

Of the 2531 women aged 15–49 years eligible for interview, 1911 (75.5%) were successfully interviewed, with 1796 (70.1%) measured for weight and height. Information captured included demographics, socioeconomic status, birth history, maternal and newborn health, women's health and anthropometric measurements.

Of the 1384 children less than 5 years old eligible for measuring, we measured the height and weight for 1281 (92%). After cleaning and merging all the separate data files together, 1104 children were included in the analyses. Of those 1104 children, complete and valid data were captured for height and age from 1009 children, weight and height from 1033 children, and height and age from 1068 children. The nutrition indices were analysed separately and only children with complete data were included.

Variables

Outcome variables

The primary outcome for this study is undernutrition in children under 5 years. Three widely accepted anthropometric indices—height-for-age (stunting), weight-for height (wasting) and weight-for-age (underweight)—are used to assess nutritional status. Team members used stadiometers to capture the height (24–49 months) and recumbent length (<24 months) to the nearest 0.1 cm for those children less than 5 years. SECA scales with digital displays were used to measure weight to the nearest 0.1 kg. Z scores for height-for-age (HAZ), weight-for-height (WHZ) and weight-for-age (WAZ) were calculated using the 2006 WHO Child Growth Standards.[31] All anthropometric indices were analysed as dichotomous variables: *0, normal if Z score ≥−2 SD; 1 (stunted, wasted, underweight) if Z score <−2 SD.*

Height-for-age is a measure of linear growth. A low height-for-age or stunting reflects failure of a child to reach his or her full growth potential due to chronic poor health and or nutrition.[32] Stunting is largely considered irreversible after the first 2 years of life, and as such, the interpretation varies depending on a child's age. Stunting in a child less than 2–3 years indicates a child is failing to grow, whereas stunting in an older child means he or she has failed to grow.[32]

The weight-for-height is a measure of body weight in relation to height. In comparison to stunting, weight-for-height is a reflection of recent or severe weight loss often associated with severe deficiency in calorie intake or illness.[32]

Weight-for-age is a measure of body weight in relation to age and reflects both chronic and acute malnutrition.[32]

Explanatory variables

Sixteen independent variables were included. These variables were selected after reviewing the literature and the UNICEF Conceptual Framework of Determinants of Undernutrition[6] and categorised into three main groups: community characteristics, household characteristics and

Table 1 Independent variables included in the multilevel mixed logistic regression models for stunting, wasting and underweight

Level	Variables
Community	Village assembly
Household	No. of household members Wealth index Food security Drinking water source Condition of toilet facilities Maternal education Paternal education Maternal age at birth Maternal height Maternal BMI
Individual	Birth order Sex of child Age of child Had diarrhoea in 2 weeks prior Ever breastfed

BMI, body mass index.

individual characteristics. Variables included in the analysis models are listed in table 1.

Community characteristics

VA was included as a predictor to assess whether place of residence was a significant risk factor for child's nutritional status.

Household characteristics

A household wealth index was constructed from an inventory of household (radio, television, DVD player, mobile phone, watch, refrigerator, electricity), transport (bicycle, motorbike, car, truck, canoe, motorboat), productive assets (agricultural tools, fishing gear rice mill, 4wheel tractor) and livestock ownership (pig, chicken, goat, other) using principal component analysis.[33] Households were then ranked according to their scores and split into wealth quintiles, each group equating to approximately 20% of the population.

Household food insecurity was measured using the Household Food Insecurity Access Scale (HFIAS), developed by the Food and Nutrition Technical Assistance (FANTA) project.[34] The scale relates to three domains of food security access: anxiety about the households' food supply, insufficient food quality (variety and preference) and insufficient food intake.[34]

Other household variables include number living in the household, highest education level of parents (primary or lower, high school or higher), maternal age at birth (>40 years, 30–39 years, 20–29 years, <20 years), maternal height (≥155 cm, 150 to <155 cm, <150 cm), maternal body mass index (BMI) (kg/m^2): underweight (<18.5), normal (18.5 to <25), overweight (25.0 to <30), obese (>30). Main drinking water source and type of toilet facilities were categorised as improved or unimproved using the classification adopted by the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation.[35]

Individual characteristics

Child's sex, child's age 0–5 months (exclusive breastfeeding), 6–23 months (appropriate complementary feeding) and 24–59 months, birth order (first, second, third born), whether the child had ever been breastfed and whether the child had experienced diarrhoea in the past 2 weeks were all included in the individual level group.

Analysis

Data analysis and manipulation was conducted using R Studio V.1.2.1335 and R V.3.6.0. Most of the variables analysed had complete data due to the way in which information was captured and validated using a digital platform. Any missing variables were excluded from the analysis. The data were checked for inconsistencies and outliers were removed prior to analysis. For example, children and women with abnormal date of birth were excluded. Children were also excluded from the analysis if their Z scores fell outside the WHO Child Growth Standards plausible range (HAZ <−6 or >6, WHZ <−6 or >5, WAZ<−5 or >5).[31] Descriptive statistics were used to generate frequencies to summarise and explore the variables. This was followed by an exploratory bivariate analysis to compare each of the variables by the three study outcomes of stunting, wasting and underweight (results not shown). To take into account the hierarchical nature of the data, multilevel multivariate logistic mixed regression models were used to analyse factors associated with stunting, wasting and underweight at the individual, household and community levels. Clustering at regional, VA and household was captured in the random component of the model. We initially compared a null model with a nested (Household (HH) within Village Assembly (VA) within Region (R)) random component with different combinations of HH, VA and R using Akaike's information criteria (AIC). The lowest AIC was found when only VA was included as a random component. Therefore, all future models were run including only VA as a random effect as adding R and HH had little impact on model outcomes in terms of inference. Three models were constructed for each study outcome. Model 1 was an empty model without predictor variables to capture variation at the VA level. Model 2 included household level factors. For model 3, significant household level factors were added to the individual level factors. The median odds ratio (MOR) was calculated at each level to assess the effect of VA on stunting, wasting and underweight at each level. A stepwise manual backward elimination process was performed on covariates in the models. Factors with a p value of <0.20 were retained in the models.[36] Only significant factors were reported (p value 0.05). The full models are provided in online supplementary material (tables 5–7). To measure the association of the explanatory variables on stunting, wasting and underweight, adjusted OR (aOR) with 95% CI were calculated using the 'odds ratio' package in R.[37]

Patient and public involvement

A community advisory committee approved the survey and advised on sampling principles. The results for the survey were disseminated through regional meetings which comprised of village leaders, government and stakeholders in each region. A comprehensive report on the survey results was provided to the Autonomous Region of Bougainville Government in 2018.

Ethics approval

The research project ethics approval was obtained by the University of Sydney Ethics Committee (Application Number: 2016/091) and the Autonomous Region of Bougainville Government.

RESULTS

Sociodemographic characteristics of study population

Over half the households (53.9%) were in the North, 11.6% in Central and 34.5% in the South, reflecting the population density in each region. The Central region has a smaller population due to the remote, mountainous terrain and as a result of the civil war and migration associated with closure of Panguna mine. Over half (57.2%) the households had five or less members. Most mothers were married or in a de facto relationship (93.6%). The majority of mothers (71.5%) and fathers (70.1%) had primary level education, with a small percentage having no formal education (3% mothers and 3.8% fathers). Women mostly gave birth between the ages of 20 and 29 (58.7%), with 8.4% giving birth before 20 years of age. Children had a mean age of 28.33 (SD ±16.63) months, with most children in the 24–29 months age category. There were slightly more male (52.1%) than female (47.9%) children in the study sample (table 2). The sex ratio of male to female was 1.07, which is consistent with previous studies.[16]

Nutritional status of children under 5 years

The overall nutritional status of children under 5 years is presented in table 3. The low means for each of the nutrition indices indicate the study population has poorer nutrition outcomes compared with the WHO growth reference standards. Overall, 36.5% of children were stunted, 4.7% wasted and 15.9% underweight.

Factors associated with stunting

The null model shows that the MOR for VA was 1.59, when all factors were added into the model, the MOR decreased slightly, demonstrating the consistent role of VA in the model. Results showed that children living in households with unimproved toilets had greater odds of being stunted (aOR=1.71, 95% CI 1.14 to 2.55) compared with those households with improved toilet facilities. Maternal height was also a significant independent predictor of child stunting and the odds increased as maternal height decreased. The odds of having a stunted child were 2.37 (95% CI 1.29 to 4.35) times higher among women measuring <150 cm tall and 1.52 (95% CI 1.02 to 2.26) times higher among women measuring 150–<155 cm tall compared with those women ≥155 cm tall (table 4).

Table 2 Sociodemographic characteristics of study population

Characteristics	Frequency (n)	Percentage (%)
Region		
North	595	53.9
Central	128	11.6
South	381	34.5
Wealth quintiles		
Lowest	214	19.4
Second	220	19.9
Third	242	21.9
Fourth	229	20.7
Highest	199	18.0
No. of household members		
≤5	631	57.2
>5	473	42.8
Marital status		
Married/de facto	975	93.6
Previously married (divorced/widowed)	49	4.7
Single	18	1.7
Maternal education		
Primary or lower	748	71.5
High school or higher	298	28.5
Paternal education		
Primary or lower	607	70.1
High school or higher	259	29.9
Maternal age at birth		
>40 years	32	3.2
30–39 years	294	29.7
20–29 years	582	58.7
<20 years	83	8.4
Child's sex		
Female	529	47.9
Male	575	52.1
Child's age		
Mean		28.33 (±16.63)
0–5 months	111	10.1
6–23 months	347	31.4
24–59 months	646	58.5

Table 3 Prevalence of stunting, wasting and underweight in children <5 years

Nutritional status	Mean (±SD)	Frequency, n (%)
Height-for-age Z score (HAZ)	−1.37 (±1.89)	
Stunting (HAZ −2 SD)		368 (36.5)
Weight-for-height Z score (WHZ)	0.00 (±1.28)	
Wasting (WHZ −2 SD)		49 (4.7)
Weight-for-age Z score	−0.80 (±1.41)	
Underweight (WAZ −2 SD) (WAZ)		170 (15.9)

Factors associated with wasting

No significant factors were found to be associated with wasting among the under-5 children in the multilevel mixed regression analysis. This is likely due to the small number of children who were wasted in the study sample (n=49). Maternal height between 150 and <155 cm was borderline significant with a p value of 0.05. The odds of a child being wasted was 2.17 (1.00–4.74) times higher among women measuring 150 to <155 cm compared with those ≥155 cm. In the bivariate analysis, maternal height, birth order and child's age all reported a p value of <0.05. We observed higher than expected numbers of wasted children in the shorter maternal height categories (<155 cm), younger children (0–5 months, 6–23 months) and among second and third born children.

Factors associated with underweight

The null model shows that the MOR for VA was 1.27, when all factors were added into the model, the MOR increased only slightly, demonstrating the consistent role of VA at each level. Poor drinking water, poor toilet facilities, child's age and birth order were all significant predictors for underweight in children under 5. Children from households with unimproved drinking water sources (aOR=1.97, 95% CI 1.19 to 3.29) and unimproved toilet facilities (aOR=2.11, 95% CI 1.16 to 3.82) had a higher odds of being underweight. The odds of a child being underweight increased with birth order. The odds of underweight in third-born children was 6.77 (95% CI 2.00 to 22.82) times the odds of first-born children and the odds of second-born children was 1.92 (95% CI 1.09 to 3.36) times that of first-born children. Compared with children aged less than 6 months, children aged between 6–23 months (aOR=4.83, 95% CI 1.36 to 17.24) and 24–59 months (aOR=4.59, 95% CI 1.29 to 16.26) were found to have a higher odds of being underweight (table 4).

DISCUSSION

This study assessed the nutritional status and factors associated with stunting, wasting and underweight from a sample of 1104 children under 5 years from cocoa-farming communities in Bougainville. The analyses showed that 36.5% of children were stunted, 4.7% wasted and 15.9% underweight; results far higher than the WHO Western Pacific Region averages of 6.2% for stunting, 2.1% for wasting and 2.4% for underweight.[38] Our study found that the odds of stunting increased significantly among children from households with unimproved toilet facilities, those born to mothers of shorter stature and children older than 6 months of age. The odds of a child being underweight was higher among children from households with unimproved toilet facilities, unimproved drinking water sources, children aged over 6 months and second-born and third-born children. In 2019, the ARoB voted overwhelmingly for independence from PNG. These findings provide an evidence base for relevant stakeholders and policymakers to support the development of interventions aimed at improving the nutrition and livelihoods of smallholder cocoa-farming families within Bougainville.

Household characteristics

Our analyses demonstrated that children from households with unimproved toilets had increased odds of being both stunted and underweight compared with those with improved toilets. A study in Timor Leste similarly found that children from households with flushable toilets had, on average, significantly higher height-for-age Z scores compared with those without.[39] Households without access to clean water sources were also more likely to have an underweight child. These findings support research linking water and sanitation and child undernutrition in other places.[40] Household environs, which include poor water and sanitation facilities and practices, in particular open defecation, increases the risk of infectious diseases and subsequently the uptake of nutrients from food. Persistent infections over time can lead to environmental enteric dysfunction (EED) which is thought to cause growth faltering in children due to chronic inflammation of the intestine and reduced nutrient absorption.[41] The important role water, sanitation and hygiene (WaSH) play in child nutrition and development outcomes is of great importance for Bougainville where over two-thirds of households use unimproved toilets and one-third do not have safe drinking water.

While WaSH programmes have benefits,[40 42] there remains uncertainty about the effectiveness of some of them. Three recent randomised controlled trials[43–45] of WaSH interventions (water treatment, handwashing and sanitation) found limited effect on nutritional outcomes in high burden areas, leading to experts calling for more integrated 'Transformative WaSH' approaches that address the community-specific exposures and burden of EED.[46 47] Our study area where 61% of people own livestock raises the potential dangers posed by animal faecal hazards. These findings provide the evidence supporting the ARoB Government strategic development plan 2018–2022, prioritising WaSH activities.

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Table 4 Multilevel logistic regression analysis for child malnutrition and community, households and individual level factors (p<0.05)

	Null model			Stunting (<–2 SD)			Null model			Wasting (<–2 SD)			Null model			Underweight (<–2 SD)		
Factor	OR	(95% CI)	P value	OR	(95% CI)	P value	OR	(95% CI)	P value	OR	(95% CI)	P value	OR	(95% CI)	P value	OR	(95% CI)	P value
Toilet facility																		
Improved				1.00												1.00		
Unimproved				1.71	(1.14 to 2.55)	0.01										2.11	(1.16 to 3.82)	0.01
Drinking water source																		
Improved																1.00		
Unimproved																1.97	(1.19 to 3.29)	0.01
Maternal height																		
≥155 cm				1.00														
150–155 cm				1.52	(1.02 to 2.26)	0.04												
<150 cm				2.37	(1.29 to 4.35)	0.01												
Child's age																		
0–5 months				1.00												1.00		
6–23 months				3.27	(1.57 to 6.78)	<0.01										4.83	(1.36 to 17.24)	0.02
24–59 months				2.82	(1.40 to 5.67)	<0.01										4.59	(1.29 to 16.26)	0.02
Birth order																		
First																1.00		
Second																1.92	(1.09 to 3.36)	0.02
Third																6.77	(2.00 to 22.82)	<0.01
Random-effects variance																		
VA (MOR)	1.59			1.55			1.04			1.40			1.27			1.34		

*Only significant factors with a p<0.05 are reported.
MOR, median odds ratio; VA, village assembly.

Maternal characteristics

Maternal height was a significant predictor of stunting and the odds of having a stunted child increased as maternal height decreased, a finding consistent with a number of studies from LMICs.[48–50] Maternal stature is a combined indicator for both genetic and environmental stresses on a woman during the key growth years. Women of short stature have a higher risk of having a baby that is small-for-gestational age or low birth weight (LBW). These babies are at greater risk of infections and when infected do not absorb nutrients, leading to stunted growth.[51] Risk of infection is higher in Bougainville where most households do not have adequate toilet facilities and sanitation. This intergenerational cycle of poor maternal nutrition and poverty[52] was highlighted for action by the United Nations Standing Committee on Nutrition.[53] Breaking this intergenerational cycle to ensure babies optimally grow requires specific interventions targeting women and children at critical life stages. Women during their adolescence and when pregnant are key periods for interventions, whereas for children, the first 1000 days of life are critical.[54]

Child characteristics

This study found an association between a child's age and stunting and underweight, with the odds of both stunting and underweight being highest in children aged 6–23 months. This could be attributed to feeding practices within the first 1000 days of life. Suboptimal breastfeeding and inappropriate offering of solid foods is associated with poor nutrition outcomes in children.[48] The recent DHS conducted in PNG found the median duration for exclusive breastfeeding in the islands region was 4.6 months, with only 20.6% of children aged 6–59 months receiving the minimum acceptable diet.[55] Poor diet quality among children is a key concern for the Pacific Region.[7]

Birth order was also significantly associated with a child being underweight and the odds of a child being underweight increased with birth order. This finding is consistent with other studies that have found children born later to be susceptible to poorer nutrition and health outcomes.[56–58] One explanation for this could be that increasing numbers of children within a household puts strain on food and household resources, impacting the level of care and nutrition provided.[59] These findings emphasise the importance of family planning and reproductive health services that enable women to control when and how many children they have.

Strengths and limitations

This study is the largest nutrition study to be completed in the ARoB to date and provides essential data for the ARoB, PNG and the greater Western Pacific Region, where undernutrition remains a high burden. The study applies robust statistical methods to assess factors associated with poor nutrition in children. Some limitations include the use of cross-sectional data, from which causal inferences cannot be drawn. The smaller sample size also restricted the analysis for wasting. The information used for this study was based on mothers' recall ability. We had originally planned to include dietary diversity (a known contributor to child nutrition); however, the data collected were not valid due to inconsistencies which were identified during further qualitative research conducted in the study villages.

CONCLUSION

The findings demonstrate a high prevalence of undernutrition, specifically stunting, among Bougainville cocoa-farming households. Factors found to be significantly associated with poor nutrition outcomes in children under five are unsafe drinking water and sanitation, maternal height, birth order and age of the child. These findings reinforce the multidimensional nature of undernutrition and the need for interdisciplinary approaches to address it. Sustained improvements to undernutrition and the livelihoods of cocoa-farming communities in the ARoB cannot be achieved without interventions that simultaneously target key life stages for women and children and the underlying social and environmental factors. The long-term consequences of undernutrition are costly due to losses in human productivity, losses from poor cognitive development and reduced schooling, and losses due to increased healthcare costs. These findings provide a much-needed evidence base for future programmes and policy decisions on Bougainville's journey to independence.

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Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not required.

Ethics approval The research project was approved by the University of Sydney Ethics Committee (Application Number: 2016/091) and the Autonomous Region of Bougainville Government. Participants were provided with detailed information about the project prior to commencing the survey and were informed that their

participation was voluntary and that they could choose to withdraw at anytime. Informed consent was obtained from all individual respondents or caregivers for children under the age of 16 at the time of survey.

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