Human Ecology (2018) 46:787–799
https://doi.org/10.1007/s10745-018-0027-6

Rural Livelihood Variation and its Effects on Child Growth in Timor-Leste

Phoebe R. Spencer[1] · Katherine A. Sanders[1] · Debra S. Judge[1]

Published online: 28 September 2018

Abstract
Economic development introduces opportunities for subsistence households to diversify income sources. Timor-Leste is undergoing this transition; however, little is known about the patterns of household strategies and the effects of rural development on child wellbeing. We derive strategies from 190 households in two rural Timor-Leste communities and examine the links between resource strategies and child growth using linear mixed modeling. Children's z-height, z-weight, and z-BMI are well below international standards. We find agriculture remains predominantly subsistence-based, with some reliance on cash flow from government pensions and salaries. Households with stable income sources are better able to accumulate wealth, and children living in salaried households have better z-height. However, child growth is best predicted by individual-level factors rather than household ecology. Substantial variation in household strategy and little association of strategy with growth indicates there is no 'best' strategy in this transitioning environment.

Keywords East Timor · Child growth · Livelihood strategies · Development

Introduction

Across the developing world, many rural populations are reliant on subsistence agriculture for food production. As these populations transition to a cash economy and infrastructure developments facilitate movement of goods, opportunities arise for variation in resource acquisition beyond subsistence agriculture. Political development can also open up new opportunities, such as pension schemes. Households are then faced with decision-making challenges regarding resource strategies. Within new rural economies with incomplete markets participation in wage labour or small business may be unreliable or seasonal (Reardon *et al.* 1998). A solution to mediate this risk may be to maintain a traditional subsistence farm to provide a backup food source; however, household labour is often limited so cannot simultaneously be directed to subsistence farming and wage labour. Agriculture itself may be a risky strategy in a low-yield environment, especially in changing climates. Thus, households must trade off risks and rewards within an already challenging environment. In some developing countries, higher household resource levels, reflecting more successful strategies, are associated with better child nutritional outcomes (Duflo 2000; Hong *et al.* 2006; Crooks *et al.* 2007). Examining the variation in household strategies within transitioning rural communities and their effects on child growth as a nutritional indicator allows a better understanding of how households respond to new opportunities and how these strategies affect the wellbeing of dependents.

In developing economies an incorporation of market agriculture can sometimes displace household food production (Cramb *et al.* 2009), introducing an opportunity for households to transition from consuming food they grow to selling farm produce and buying food. As a result, overall market diversity of agricultural produce increases while farm-level production becomes specialized (Pingali and Rosegrant 1995). Theoretically, increased income through adopting a more successful household strategy should increase the household's nutritional security, that is, their ability to provide all members with adequate nutrition. While there is some evidence to support this relationship (von Braun 1995), other studies show a negative effect of commercialization on child nutrition (Mofya-Mukuka and Kuhlgatz 2016), and yet others find little relationship between the two (Bouis and Haddad

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10745-018-0027-6) contains supplementary material, which is available to authorized users.

✉ Phoebe R. Spencer
phoebe.spencer@research.uwa.edu.au

1 School of Human Sciences, University of Western Australia, Perth, Australia

1990; Carletto *et al.* 2017). It therefore appears that the relationship between increased agricultural income and better child outcomes is mediated by context-specific factors, for example, health and sanitation, nutritional knowledge, and control of market income (Bouis and Haddad 1990; Kennedy and Peters 1992).

In Timor-Leste, subsistence agriculture is the main livelihood strategy for the majority of the rural population. Subsistence in Timor-Leste is predominantly plant-based, with staple crops including rice and cassava as well as crops introduced by the Portuguese such as maize and beans (Thu and Judge 2017). The country is food insecure (households do not have enough food) and thus a net importer of food, predominantly of rice but more recently animal products (Andersen *et al.* 2013). Food insecurity is attributed to the low quality of soils, poor-yielding crop varieties, and variable rainfall (Molyneux *et al.* 2012). In the absence of food security, household nutritional security is difficult to achieve. While commercial agriculture in Timor-Leste is limited, the more general phenomenon of rural economy commercialization is still occurring, with some increase in opportunities for income and employment. In larger rural centres, salaried work in education, health, and local administration is available. Some people run small businesses and wage labour is also available through farm work for others or local project work. The rural economy is aided by cash flow from government pension schemes. The veterans' pension program is a highly valuable income stream available to those who participated in the resistance movement against the Indonesian occupation (Kent and Wallis 2013). The lowest pension amount under this scheme is US$276 per month, far above the income earned by the majority of rural Timorese. Government workers, for example, earn approximately US$200 per month. Pensions are also available to those over the age of 60, valued at US$30 per month, and almost all who are eligible currently receive this benefit (Bongestabs 2016). The *Bolsa da Mãe* is a small cash transfer available to the poorest households with school-aged children, providing US$5 per child per month for up to three children in a household (Fernandes 2015). Thus, in rural Timor-Leste within an environment of subsistence agriculture opportunities for income diversification exist, supported by government cash transfers.

Child growth in Timor-Leste is well below international standards and the proportion of children affected by malnutrition has decreased little in recent years (Deen *et al.* 2013). On a national level, widespread poor growth is attributed to limited availability of nutritional foods and high child illness burden (Deen *et al.* 2013). Previous research conducted in two (upland and lowland) populations in rural Timor-Leste indicates growth faltering in early development (Spencer *et al.* 2018). Furthermore, male children in these areas have poorer growth than females (Sanders *et al.* 2014; Spencer *et al.* 2018). As the country's economy grows, there has been little research on how rural areas are affected by development and almost none on what changes (if any) are having a positive effect on child growth. The research in the two populations found links between household composition and growth but no effect of agricultural indices in the upland population (Reghupathy *et al.* 2012), and a positive relationship of agriculture to growth in a coastal, lowland area (Spencer *et al.* 2017).

In this paper, we characterize household resource acquisition strategies over the same upland and lowland populations in rural Timor-Leste in order to better understand the variation in household ecology in transitioning rural economies. We use reports of household livelihoods to determine suites of practices relating to household-level constraints, opportunities, and labour resources. We then investigate the effects of these household strategies on child growth in order to better understand the causes of poor growth and the relative effects of household resources, diet, and health and sanitation.

Methods

Data were collected in May–June 2016 (post rainy season) in both the Natarbora and Ossu subdistricts of Timor-Leste. Natarbora is located in the flat coastal plains of the country's south (5 – 50 m above sea level) and Ossu is in the mountains of the central east (600 – 1000 m above sea level). Both sites have schools, a health centre, and a local market. Households were originally recruited in 2009 (Ossu) and 2012 (Natarbora) for a longitudinal study of family ecology and child growth, with additional households recruited in each subsequent data collection period (Reghupathy *et al.* 2012; Spencer *et al.* 2017). Households were originally recruited using snowball sampling on a nearest-neighbour basis, provided households had resident children and were willing to participate. For this paper, all participating households were visited in 2016 (n = 190). Our sample represents 21% of all households in the Natarbora area and 8.3% of all Ossu households, and covers the breadth of variation across geographical space and resources within each area (Ministry of Finance 2010). Substantial development has occurred since households were originally recruited, for example, the introduction of electricity and an increase in opportunities for small business. Thus, more recent data better characterize a rural population under economic transition.

During visits, all resident children were measured for height (measuring tape) and weight (electronic scale to 0.1 kg) using standard protocol (de Onis *et al.* 2004). For children too young to stand upright unassisted, recumbent length was measured. All children were measured wearing a light layer of clothing (shorts/skirt and a t-shirt). Height is a measure of long-term growth and reflects the accumulation of past conditions, whereas weight and body mass index (BMI) are more sensitive to short-term environmental changes. All mothers were also measured for height.

The lead female in each household (usually the children's mother) was interviewed to ascertain household demographics and resource availability. In the absence of the lead female, the eldest female or male resident was interviewed. The interview was conducted by PRS in the national language, Tetun, with the aid of a local research assistant. In Ossu, where some households speak Makassae and Kai Rui languages, the interview was conducted either in Tetun by PRS with translation into Makassae or Kai Rui as required by a research assistant, or entirely by the research assistant in Makassae or Kai Rui in the very few households that did not speak any Tetun ($n = 5$). Demographics included the age, sex, and relationship to lead female of each household member (defined as a person who slept and ate in the household). Household resource information included forms of income received by any household member (including salaries, pensions, or other income) and the current agricultural practices of the household (if they were cultivating a garden or rice field, what crops they were growing, and animal ownership). Health status of each child during the preceding month (ill or not ill) was also determined through recall by the mother or lead female. Due to the difficulties in obtaining accurate food intake data on a per-child basis, nutritional intake was proxied by household-level dietary diversity. To determine dietary diversity, the lead female of the household was asked to recall the food the family had eaten the day prior, prompted by what they ate and drank for breakfast, for lunch, and for dinner. If any child within the household ate differently at any meal, this was also recorded. During methods development, we also asked about snacks eaten outside of meal times; however, participants found this concept confusing and consistently reported not eating other than at main meals.

Data Coding and Statistical Analyses

Growth measurements were converted to z scores for comparison to the World Health Organization using the Anthro and AnthroPlus packages in IBM SPSS Version 22. Children with z scores <5 or > −5 were removed as outliers ($n = 4$). Outliers are likely to be the result of measurement error in the height of young children, who are more difficult to measure, or age inaccuracies. Variables relating to household composition and resources were coded as continuous or categorical variables (see Supplementary File 1 for full list of variables). Data were coded in such a way as to attain, as closely as possible, a normal distribution while still meaningfully capturing the range and frequency of responses. Food recall data were recoded as number of food groups eaten in the 24-h period to create a household dietary diversity score (DDS; Table 1). The DDS captures exposure to macro- and micronutrient groups, where a greater number of groups indicates a higher dietary quality (Ruel 2003). To create a food variety score (FVS), the numbers of distinct food items across all food groups were summed. FVS also gives an indicator of dietary quality. Both DDS and FVS can be used as indicators of micronutrient adequacy (Steyn *et al.* 2006). For example, if a reported daily intake contained bread for breakfast, rice, cassava leaves, and papaya leaves for lunch, and rice and *kangkong* (water spinach) for dinner, this would result in an FVS of 5 (as there are five different food items) but a DDS of only two food groups (staple starches and Vitamin A-rich foods). The 'other' food group items were included in the FVS but not the DDS.

Household variables were examined for a bivariate relationship with either z-height-for-age or z-BMI-for age. Those variables showing a trend ($p < 0.1$) for any growth measure were retained for modeling (see Supplementary File 1). Some variables not showing a trend were retained based on their importance in household strategy or child growth theory. The variable relating to rice crop cultivation, while significantly related to growth, was discarded as too few households were cultivating ($n = 15$), and variances were therefore highly unequal.

Principal component analyses (PCA) were performed to aggregate interrelated predictor variables that could then reveal "strategic" sets of practices. Separate PCAs were performed on three clusters of variables relating to household composition, to household income, and to agricultural practices. Dietary quality was included in the agricultural practices PCA, and measured as FVS (DDS showed little variation among households and no relationship with child growth). Components were retained based on percentage of variance explained and scree plot inspection. Varimax orthogonal rotation was performed in all analyses to aid interpretation (Kaiser 1958). Household principal component scores were then input as continuous predictor variables for modeling child growth outcomes. Nominal variables, or variables that did not logically fit into any of the three factors were kept as separate predictors.

All statistical modeling was performed using linear mixed models that included household ID as a random factor to account for the clustering of children within households. Models used either z-height-for-age or z-BMI-for-age as the dependent variable. The starting model for each growth measure included the same list of variables (see Table 6 footnote). Models were reduced via stepwise elimination of the least significant variable, until removal of the least significant variable resulted in an increase in the Akaike information criterion (AIC; Burnham *et al.* 2011). Ossu and Natarbora households were modeled separately. Both are representative of rural Timor-Leste; however, the sites differ in child growth and in socio-ecological factors (Thu and Judge 2017). Modeling the sites separately allows better understanding of the variation that exists within rural Timor-Leste.

Table 1 Food groups and examples of items included within groups for the calculation of the dietary diversity score

Food group	Examples of included items
Meat	Beef, pork, chicken, fish, tinned tuna, deer, possum
Legumes	Mung beans, tofu, tempeh, other beans
Staple starches	Rice, bread, cassava, potato, boiled plantain, doughnuts, cake, noodles
Vitamin A-rich foods	Leafy greens (e.g. water spinach, papaya leaves), sweet potato, pumpkin
Vegetables	Eggplant, bitter gourd, carrot
Fruits	Papaya, banana, jackfruit, papaya flower, banana flower
Eggs	Eggs
Dairy	Milk (tinned or powdered)
Other	Tea with sugar, water with sugar

The 'other' food group items were included in the food variety score but not the dietary diversity score

Including mother's height in the model excluded the vast majority of fostered children (117 of 132), as their mothers were not available to be measured. Fostered children in Timor-Leste do not incur a growth cost relative to biological children (Judge *et al.* 2012; Spencer *et al.* 2017). For the purpose of analysis, we excluded fostered children with missing data. We did, however, include a household-level measure of fostering via the number of children fostered into the household. This variable then accounts for the effect of fostering on resident biological children.

Results

Characteristics of the Sample

A total of 345 children in 94 Natarbora households and 392 children in 96 Ossu households provided data. Approximately equal numbers of males ($n = 364$) and females ($n = 373$) participated. Children ranged in age from one month through 18 years old, as per the availability of WHO standards. Children were classified into age groups for analyses (Supplementary File 2). As classified by z-BMI-for-age, most children were normal or thin, with only 2.9% of Ossu children and 4.0% of Natarbora children characterised as overweight or obese (Table 2). Maternal height ranged from 138.1 cm – 165.9 cm with a mean of 150.95 cm (SD = 5.32, $n = 210$).

Table 2 Number of children in Ossu and Natarbora in each nutritional group (relative to z-BMI-for-age)

Nutritional group (z-BMI-for-age)	Ossu	Natarbora
Severe thinness (<−3)	7	11
Thin (−3 < X < −2)	42	59
Normal (−2 < X < 1)	324	246
Overweight (1 < X < 2)	8	11
Obese (>2)	3	2

Thirty-one mothers (14.8%) were classified as stunted based on DHS classification, that is, height below 145 cm.

The number of children, number of adults, and total household size did not differ significantly between sites. Households in Natarbora were more likely to have a grandfather present than were Ossu households ($\chi^2_{(1)} = 7.52$, $p = .006$), and showed a trend toward more grandmothers ($\chi^2_{(1)} = 3.67$, $p = .055$).

Almost all households reported animal ownership (96.3%), and the vast majority had access to some cash income (95.8%). Most households (79.5%) were growing crops in their gardens. Three-quarters (77.7%) of Natarbora households received a pension, compared with 43.8% of Ossu households ($\chi^2_{(1)} = 22.86$, $p < .001$). Additionally, Natarbora households were more likely to be receiving high value pensions than were Ossu households ($t = 3.39$, $p = .001$), with the predominant difference being the number receiving veterans' pensions, which is the highest dollar value pension (17 households in Natarbora versus seven households in Ossu). There is a common pattern of appliance accumulation across both subdistricts, first lights, then mobile telephones, then televisions, rice cookers, and kettles. On average, households reported having 4.21 (SD = 2.11) appliances, with a maximum of 11 ($n = 1$). Developed toilets (defined as a toilet having a water flush system of some type) were more common in Natarbora (76.6% of households) than in Ossu (23.4%; $\chi^2_{(1)} = 9.65$, $p = .002$).

Overall, dietary diversity scores (DDS) were low with most households eating only two or three food groups on a sampled day, and a maximum of five food groups in a few households ($\bar{x}$ = 2.85, SD = .85). Food variety scores (FVS; number of food items consumed) varied more among households and had a higher mean ($\bar{x}$ = 4.54, SD = 1.51). Higher FVS than DDS indicates that most households were eating multiple types of food within the same food group. FVS did not vary by site ($t = -1.58$, $p = .116$; Fig. 1); however, households in Natarbora ($\bar{x}$ = 3.03, SD = .88) had a higher DDS than Ossu households ($\bar{x}$ = 2.68, SD = .79; $t = -2.93$, $p = .004$). Households receiving a salary had a higher DDS than those

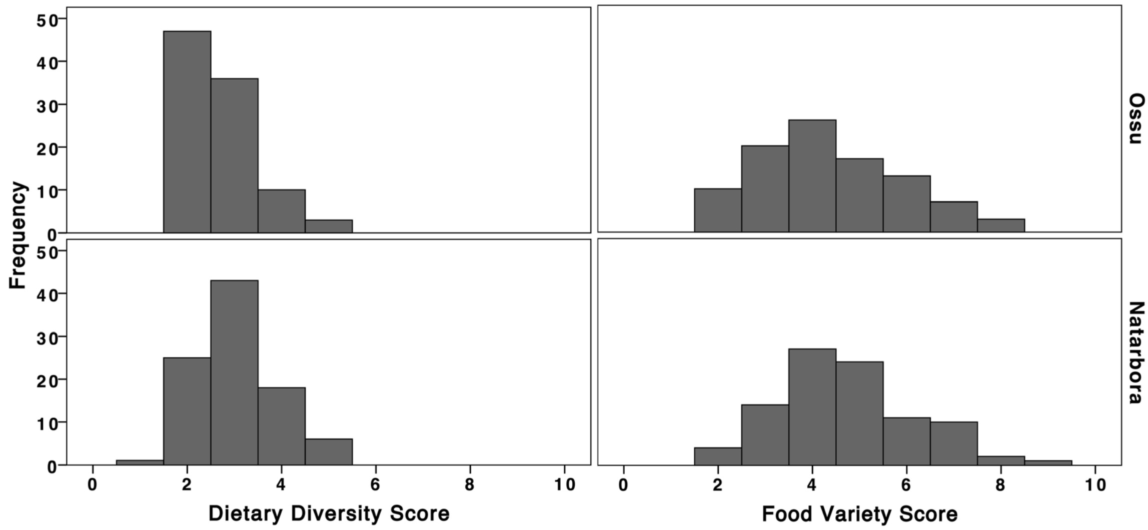

Fig. 1 Dietary diversity score (left; total number of food groups) and food variety score (right; total number of unique food items) frequency for all households providing food recalls in Ossu (top; $n = 96$) and Natarbora (below; $n = 93$)

without a salary ($t = -2.315$, $p = .022$), whereas FVS did not differ by salary ($t = -1.277$, $p = .203$).

Principal Component Analyses

In order to conceptualize household strategy, principal component analyses were run on household variables showing either a trend with growth measures, or having a theoretically strong background. Household composition was explained by three components (Table 3): fostering households with grandparents present (HC 1), households with many biological children and more adults other than grandparents (HC 2), and households that fostered out children (HC 3). Three agricultural strategies emerged (Table 4): households with chickens and frequently ate eggs had higher FVS (Ag 1); households specializing in large animals (Ag 2); and households that had higher FVS and higher crop diversity (Ag 3). Household income was best explained by three components (Table 5):

Table 3 Varimax rotated component matrix for household composition principal component analysis

	Component		
	HC 1	HC 2	HC 3
grandfather present	**.92**	.02	.01
grandmother present	**.91**	−.07	−.07
# adults (exc. grandparents)	−.02	**.80**	−.19
# biological children	−.02	**.76**	.33
# children fostered out	.08	−.08	**.84**
# children fostered in	**.35**	−.33	**−.57**
variance explained	32.76%	22.28%	17.00%

Three components explain 72.04% of the total variance. Major loadings (>0.35) are indicated in bold

households with high value pensions (I 1); households with salary income and more appliances (I 2); and households reliant on agricultural income (I 3).

While components within one PCA are, by definition, independent of each other, we examined the relationships between components of different clusters to better understand household strategies. Five households had missing data for agriculture components, so were excluded from all analyses. Pearson correlations showed relationships between factor scores (Table 6). Large, fostering households with grandparents (HC 1) also had large animals (Ag 2), high value pensions (I 1), or salaries and more appliances (I 2). Cows and pigs are expensive, so greater numbers reflect the ability to invest over time, as does accumulating more appliances. Thus, these households are able to use their stable incomes (salaries and/or pensions) to accumulate wealth. Having a salary was also positively related to having a more varied diet, eating eggs more often, and owning chickens (Ag 1), and with investing less in crop diversity. Households reliant on agricultural income (I 3) tended to be those without grandparents, but with more adults and more biological children (HC 2), and invested in large animals (Ag 2).

Linear Mixed Models

We performed linear mixed modeling (LMM) to determine how the various factors affect child growth, including household and individual-level factors. All models started with the variables relating to individual factors (age group, sex, health – ill or not in past month, and mother's height), factor scores from the income PCA, factor scores from the household composition PCA, factor scores from the agriculture PCA, garden cultivation status, type of toilet, drinking water treatment, and

Table 4 Varimax rotated component matrix for agricultural variables principal component analysis

Variable	Component		
	Ag 1	Ag 2	Ag 3
frequency eat eggs	**.77**	−.01	−.03
# chickens	**.71**	.15	−.01
FVS	**.58**	.01	**.42**
# pigs	.17	**.84**	−.17
# cows	−.04	**.76**	**.36**
total crops	.03	.06	**.89**
variance explained	28.99%	19.17%	16.43%

Three components explain 64.58% of the total variance. Major loadings (>0.35) are indicated in bold

subdistrict (Natarbora or Ossu) (see Supplementary File 3 for categories of variables included in analyses).

Mother's height was the strongest independent predictor of child z-height-for-age, with taller mothers having taller children (Table 7). Female children had better growth than did male children, even after accounting for normal sexual dimorphism in height, which is included in the WHO standardization. Children living in households with fewer co-resident adults and biological children had better growth than households with other family structures. Households receiving at least one salary income (associated with more household appliances) had children who were taller for age than in households with other incomes. Children were taller in Natarbora than in Ossu; however, Natarbora mothers ($\bar{x}$ = 152.43 cm, SD = 5.69) were taller than Ossu mothers ($\bar{x}$ = 149.57 cm, SD = 5.45; ($t = -3.72$, $p < .001$). When a mother's height by subdistrict interaction term was included in model, the interaction term itself was not significant; however, the site variable was no longer significant. This indicates that much of the effect of field site on child z-height-for-age is captured by differences in mother's height.

Table 5 Varimax rotated component matrix for household income principal component analysis

Variable	Component		
	I 1	I 2	I 3
pension value	**.86**	.13	−.09
# pensions	**.79**	−.29	.07
# appliances	.08	**.83**	.15
receive a salary	−.21	**.77**	−.19
agricultural income	−.04	−.01	**.98**
variance explained	32.20%	24.14%	20.16%

Three components explain 76.5% of the variance. Major loadings (>0.35) are indicated in bold

Table 6 Pearson correlations of factor scores (Ag 1: high FVS, chickens and frequently eat eggs, Ag 2: large animals, Ag 3: high crop diversity; I 1: high value pensions, I 2: salary and more appliances, I 3: farm income; HC 1: grandparents and fostered children, HC 2: many biological children and adults, HC 3: foster out children) from principal component analyses of all households ($n = 185$)

	Ag 1	Ag 2	Ag 3	I 1	I 2	I 3
HC 1	−.01	.34**	.07	.34**	.22**	.02
HC 2	.15*	.08	.05	−.09	.01	.21**
HC 3	−.17*	−.11	−.04	−.03	−.12	.03
Ag 1				−.08	.26**	.06
Ag 2				.23**	.06	.16*
Ag 3				.02	−.16*	.07

**correlation is significant at the $p < .01$ level

* correlation is significant at the $p < .05$ level

Child z-BMI-for-age was best predicted by individual characteristics rather than any household-level measure (Table 8). Younger children had higher z-BMI than older children, with the best z-BMI in the youngest age group. Similarly to height, females had better z-BMI than did males. Ossu children had better z-BMI than did Natarbora children, probably because Ossu children are shorter, and short stature inflates BMI. The subdistrict by sex by age group interaction term was significant. Until 5–10 years of age, males and females in each subdistrict are more similar to each other than to the same sex in the other subdistrict (Fig. 2). After 10 years of age, the z-BMI of females increases such that both females and males are more similar to each other across subdistricts. Overall, children who were healthy in the past month had better z-BMI than children who were recently sick. There was no interaction between illness and subdistrict, age, or sex. Mother's height was not a significant predictor in this model; however, its elimination resulted in a large increase in AIC, so it was retained in the final model.

WHO standards for weight are only available until the age of ten; however, weight was modeled to examine the predictors of short-term growth in the younger children, as results from height and BMI models suggested strong age-related differences in growth. Mother's height was the strongest predictor of z-weight-for-age, with taller mothers having heavier children (Table 9). Similarly to z-BMI, the youngest age group (0–2 years) showed the highest weight for their age. While sex was a significant predictor of growth in both z-BMI and z-height-for-age, it was not retained in the z-weight-for-age model. Children aged 0–2 years in households with a developed toilet were heavier for age compared with children without toilets ($t = 2.17$, $p = .031$). This may reflect the influence of better household sanitation on child illness, in that children with a developed toilet are less likely to contract diarrhoeal disease. Health status in the past month did not differ by type of toilet ($\chi^2_{(1)} = 0.07$, $p = .797$); probably because the health

Table 7 Final LMM of z-height-for-age ($n = 570$; model 1 AIC = 1577.0, final model AIC = 1555.3)

Parameter		Estimate (SE)	EMM (SE)	p
Intercept		−10.36 (1.45)		**<.001**
Subdistrict	Ossu	−.046 (.01)	−2.19 (.07)	**<.001**
	(Natarbora)		−1.73 (.07)	
Sex	female	.23 (.07)	−1.85 (.06)	**.003**
	(male)		−2.07 (.06)	
Mother's height		.06 (.01)		**<.001**
HC 2 (more adults & bio. children)		−.19 (.06)		**.002**
I 2 (salary & appliances)		.11 (.05)		**.029**
Ag 1 (chickens & high FVS)				.318

Starting model included variables: field site, age group, sex, health, mother's height, income 1, income 2, income 3, agriculture 1, agriculture 2, agriculture 3, household composition 1, household composition 2, household composition 3, garden cultivation status, type of toilet, and drinking water treatment. Household ID is included as a random factor

Results are presented as estimated marginal means (EMM) for categorical variables and parameter estimates (Covariates appearing in the model are evaluated at the following values: mother's height = 150.77 cm, I 2 = −0.05, HC 2 = 0.37, Ag 1 = 0.04.). Reference categories for categorical variables are in parentheses. Significant associations ($p < .05$) are shown in bold. Where variables are not significant, only the p value is reported

status measure includes symptoms of other illnesses including respiratory tract infection and malaria, in addition to diarrhoea symptoms. Households with higher FVS, more chickens, and who ate eggs more frequently (Ag 1) had children with slightly poorer z-weight-for-age. We would expect that children with a better dietary quality would have better growth. The negative effect may be due to the household's chickens increasing illness exposure, as chickens in Timor-Leste are free range, and often are found in houses. There was a trend for an effect of water treatment; however, the difference was only significant between those who boiled and strained their water, and those who strained only ($t = 2.55$, $p = .012$), with better

Table 8 Final LMM of z-BMI-for-age ($n = 565$; model 1 AIC = 1609.6, final model AIC = 1554.0)

Parameter		Estimate (SE)	EMM (SE)	p
Intercept		−1.46 (1.55)		.346
Age group	0–2	1.92 (.32)	−.16 (.14)	**<.001**
	2.01–5	.96 (.29)	−.73 (.12)	**.001**
	5.01–10	.62 (.26)	−1.31 (.09)	**.019**
	10.01–15	.52 (2.7)	−1.51 (.09)	.056
	(>15)		−1.28 (.12)	
Sex	female	1.11 (.35)	−.84 (.08)	**.002**
	(male)		−1.16 (.08)	
Healthy	no	−.41 (.12)	−1.20 (.11)	**<.001**
	(yes)		−.80 (.06)	
Subdistrict	Ossu	.71 (.30)	−.83 (.09)	**.020**
	(Natarbora)		−1.17 (.09)	
Age * sex * subdistrict				**.001**
Ag 1 (chickens & high FVS)				.475
Mother's height				.778

Starting model included variables: field site, age group, sex, health, mother's height, income 1, income 2, income 3, agriculture 1, agriculture 2, agriculture 3, household composition 1, household composition 2, household composition 3, garden cultivation status, type of toilet, and drinking water treatment. Household ID is included as a random factor

Results are presented as estimated marginal means (EMM) for categorical variables and parameter estimates (Covariates appearing in the model are evaluated at the following values: Ag 1 = 0.04, mother's height = 150.77 cm). Reference categories for categorical variables are in parentheses. Significant associations (p < .05) are shown in bold. Where variables are not significant, only the p value is reported

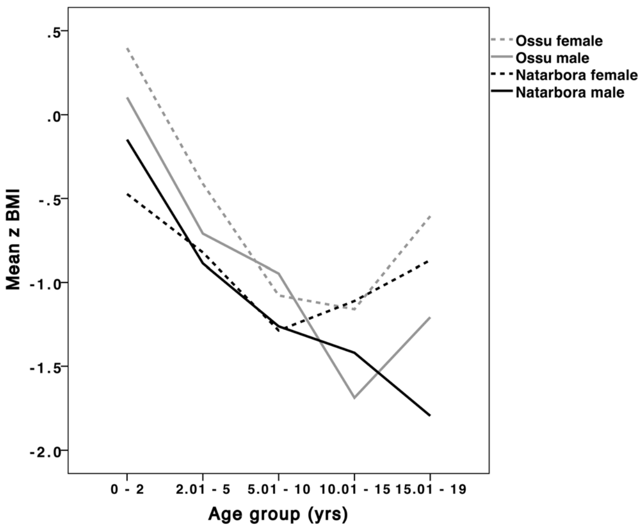

Fig. 2 Mean z-BMI by age group for Ossu children (grey lines) and Natarbora children (black lines); females are in dashed lines and males in solid lines

growth in households who only strained water. There were no differences between those who drank untreated water and those who both boiled and strained.

Discussion

Our research examines empirically derived strategies of household resource acquisition and their effects on child growth in two rural areas of Timor-Leste. Almost all households were involved in agriculture, through animal husbandry and/or garden cultivation, and almost all had access to some sort of cash income. Within these two small, rural economies, variation in livelihoods still exists, and we identify three general patterns of resource acquisition and consumption. We show that types of household income are related to both household composition and resource accumulation. Short- and long-term child growth is well below international standards in Natarbora and in Ossu. Some aspects of household strategy are related to long-term child growth. Short-term growth is mainly predicted by individual-level effects such as age and sex, indicating that external factors impinge on males and females unequally, and that ecological pressures are particularly important at certain times during development. Differences in growth with age and sex in this single year sample replicate findings using a longitudinal sample from the same two subdistricts (see Spencer *et al.* 2018 for discussion).

Rural agriculture commercialization is highly dependent on infrastructure and technology improvements, and increased demand (Pingali and Rosegrant 1995). In Timor-Leste, the commercial success of farmers is limited by inadequate transport to larger markets in the capital, and poor crop yields (Rola-Rubzen *et al.* 2010). A shift to commercialization is usually associated with more crop specialization (Pingali and Rosegrant 1995). However, in this study, there was no relationship between farm income and crop diversity, suggesting an absence of cash crop markets. Households with higher crop diversity also had greater dietary variety (FVS), possibly indicating they are primarily eating, rather than selling, garden produce. Households more reliant on farm income had more large animal investment. Livestock sale for meat consumption in Timor-Leste is increasing; however, the market for cattle is mostly in major centres and rural farmers must wait for local spot markets rather than having access to regular marketplaces (Waldron *et al.* 2016). Farm income households in this context may simply be traditional subsistence farmers who derive windfall income from opportunistic livestock

Table 9 Final LMM of z-weight-for-age ($n = 332$; model 1 AIC = 917.4, final model AIC = 895.3)

Parameter		Estimate (SE)	EMM (SE)	p
Intercept		−8.38 (1.59)		**<.001**
Age group	0–2	.88 (.16)	−1.39 (.15)	**<.001**
	2.01–5	.27 (.15)	−1.73 (.14)	.073
	(5.01–10)		−2.00 (.11)	
Mother's height		.04 (.01)		**<.001**
Water treatment				.075
Ag 1 (chickens & high FVS)				.089
Toilet * age group				.086
Toilet				.384

Starting model included variables: field site, age group, sex, health, mother's height, income 1, income 2, income 3, agriculture 1, agriculture 2, agriculture 3, household composition 1, household composition 2, household composition 3, garden cultivation status, type of toilet, and drinking water treatment. Household ID is included as a random factor

Results are presented as estimated marginal means (EMM) for categorical variables and parameter estimates (Covariates appearing in the model are evaluated at the following values: Ag 1 = 0.03, mother's height = 150.98 cm). Reference categories for categorical variables are in parentheses. Significant associations ($p < .05$) are shown in bold. Where variables are not significant, only the p value is reported sales rather than households who are moving toward a commercial model of agricultural production. There is therefore little evidence to suggest successful farm commercialization in these two communities.

In subsistence economies, agricultural productivity is partly determined by available labour. In Ossu and Natarbora, farm income households were likely to have more resident adults other than grandparents, and more biological children. More adults of working age may allow labour diversification (Barrett *et al.* 2001); for example, some household members to work in the garden or herd animals, while others sell produce at the market or provide wage labour for others. However, this household composition arrangement was associated with poorer child z-height-for-age, indicating household production cannot meet consumption demands leading to long-term undernourishment of dependent children. Ulijaszek (1995) modeled the total energy cost of dependent offspring relative to productive adults to show that households with more children spend larger portions of time with higher energy demands than production abilities. Therefore, this household composition arrangement may increase farm productivity relative to households with fewer adults, but the high numbers of dependents increases consumption relative to increases in production.

When household energy demands are high, children may contribute productively to the household. Children cannot usually be completely independent before adulthood; however they can reduce their net costs (Kramer 2005). In households with more biological children, children may expend more energy in domestic tasks, such as helping in gardens and collecting water and firewood. Physical activity causes allocation of energy away from growth, so increased child contributions may lead to poorer long-term child growth. Thus, larger household size may negatively affect child growth through both reducing child energy intake via increased division of resources and increasing energy output via increased child labour.

Accumulating purchased items indicates resources in excess of those needed for basic survival, that is, a successful resource acquisition strategy. In rural Africa, non-farm income is positively associated with measures of wealth (Barrett *et al.* 2001). Greater wealth accumulation in Timorese households was associated with non-farm income, either receiving a salary, or a high value pension. Households with salaries had a greater number of appliances, demonstrating investment in labour-saving devices such as kettles and rice cookers. Households with high value pensions owned more livestock. Timorese treat cows and pigs as investments for the future; families are expected to provide cows and pigs at weddings, funerals, and other ceremonies, so they are valued commodities (Bettencourt *et al.* 2013). Households more dependent on agricultural income were not associated with other measures of wealth, further indicating the absence of a successful market for agricultural produce in these areas.

Of the two non-farm strategies, only the salaried households were associated with better long-term child growth. Salary recipients within the household are generally the parents of the household's children. When parents are in control of the household finances, this may mean more resources are allocated directly to children, resulting in better child growth. More appliances in these households may also reduce child energy costs. Children in households with electric rice cookers and kettles may expend less energy compared with children who provide cooking fuel for the household, and therefore have more energy available for growth. Pension-recipient households tended to include grandparents, which is unsurprising as both age and veterans' pension recipients are more likely to be in the older generation. Grandparents rather than parents controlling household finances may explain the different patterns of resource accumulation between the household compositions. Investment in livestock is a more traditional practice than buying appliances; widespread electricity was only introduced in 2012 in Ossu and 2014 in Natarbora. Investing in livestock may mean resources are 'locked in' rather than freely available, and not easily transmuted in times of need. Another common use of the veteran's payment is to build a larger, cement-block house. Households with a salary may be better able to provide children with a direct, consistent stream of resources, leading to better growth.

Households with non-farm income strategies tend to have more fostered children. Fostered children in Timor-Leste do not experience a growth penalty when compared with biological children (Judge *et al.* 2012). Fostered children in households with stable cash incomes indicate that children move to wealthier families where they can be supported with little strain on their fostering household, possibly easing the demand on resources in their natal home. In Burkina Faso, where child fostering is common, while household wealth was not related to fostering decisions, households were more likely to send a child if they had more family members who were educated and fewer who were subsistence farmers (Akresh 2009). Thus, non-farm income likely plays a role in fostering decisions. In this study, households with more fostered children were also more likely to have resident grandparents. Almost all households with grandparents were three-generation families; only five of the 88 households with a grandparent were composed of solely of grandparent(s) and grandchildren. Multigenerational composition may also coalesce in higher resource households. When grandparents receive high value pensions, their children and grandchildren may be more likely to co-reside. When adult children receive a salary, grandparents may be more likely to live in their household so as to be supported by their children, and/or to provide caretaking support while parents are away working. Thus, household composition in rural Timor-Leste appears to be strongly influenced by income level and stability, with families clustering around resources.

Overall, dietary diversity (number of food groups eaten) was low (as might be expected in this pre-harvest season), with most households eating only two or three food groups in a 24-h period. In most cases, these two food groups were starchy carbohydrates from rice, and leafy greens such as *kangkong* or cassava leaves. Dietary diversity was higher in households with a salary, suggesting that purchased foods may be contributing to increased diversity. In both Natarbora and Ossu, all dairy products, and most meat, must be purchased; so wealthier households are more likely to have access to these food groups. Thus, increased household income from non-agricultural sources may increase household nutritional security to the extent that nutritious food is available for purchase. Food variety (number of unique food items) also increases with increasing crop types. In Africa, increased farm diversity is associated with greater food variety (Herforth 2010; Jones *et al.* 2014). Crop diversity also has a positive effect on dietary diversity (Pellegrini and Tasciotti 2014). Unlike other studies (Ruel 2003; Arimond and Ruel 2004), we found no relationship between diet measures and growth. This is possibly due to a lack of variation in both food variety scores and dietary diversity scores among households (Fig. 1). Other factors that compete with growth for energy, such as immune system response to illness, may be mediating the relationship between dietary quality and growth.

Where resources are scarce and children are marginally nourished, diarrhoea is a common cause of poor growth (Guerrant *et al.* 2008). Any illness can negatively affect child growth when it shunts energy away from growth to immune function. Children reporting illness in the past month had poorer short-term growth (weight-for-age and BMI-for-age) than those who were well, indicating they had insufficient resources to both maintain normal weight gain and recover from illness. Short-term growth (weight-for-age) was also poorer in young children living in households without improved toilet facilities. Better sanitation decreases exposure to enteric disease and thus improves growth (Montgomery and Elimelech 2007; Humphrey 2009). The greater effect of household sanitation on younger children has several possible explanations. Younger children may have a higher exposure to pathogens than older children within the same household, as they are more likely to play on floors and put their hands in their mouths, thus ingesting dirt contaminated with fecal matter (Ngure *et al.* 2014). The trend for children in households with more chickens to exhibit poorer growth may be due to *E. coli* transmission from chicken feces in the same way (Ngure *et al.* 2013). Furthermore, children of weaning age are particularly susceptible to diarrhoeal disease contracted through contaminated foods (Motarjemi *et al.* 1993), which is more likely if overall household sanitation is poor.

Drinking water quality is a further factor linked to child health. Little quantitative information exists on water quality in Timor-Leste, in part due to difficulties in transporting and accurately testing water samples (Michael 2006). We used household water treatment as a proxy for quality of drinking water, but found no difference in child growth between households who drank untreated water and those who boiled water before consumption. Both within and between subdistricts, there are several different water sources used by households, ranging from natural springs where water is collected as it exits the mountain, to uncovered shallow wells. The differing quality due to source variation may blur the distinction between water treatments and child outcomes. There is also evidence that improved water quality only has large effects on child health when paired with improved household sanitation (Ngure *et al.* 2014).

The strongest predictor of long-term child growth was maternal stature. This effect is partly due to genetic influences on growth, as taller parents tend to have taller children (e.g., Silventoinen *et al.* 2003); however, it is likely that some of the effect of maternal stature on child growth reflects maternal effects and prenatal growth programming (in prep). The early life environment can cause epigenetic changes of growth trajectories (Bateson *et al.* 2004). Across low- and middle-income countries, there is strong evidence that poor childhood growth originates in-utero (Christian *et al.* 2013). In rural Indonesia, the strongest predictors of infant nutritional status are factors reflecting the prenatal environment (birth weight and especially length; Schmidt *et al.* 2002). There are two potential pathways for the effect of prenatal environment on growth. Firstly, the mother's nutritional status while pregnant can set a developmental pathway for her child (Wu *et al.* 2004). Secondly, the mother's own early life and childhood (contributing to her stature) can have inter-generational programming effects on her children. In low- to middle-income countries, women who are stunted are more likely to have stunted children (Özaltin *et al.* 2010), as shorter stature in women is associated with decreased uterine blood flow and uterine volume, both of which are linked to foetal growth restriction. Furthermore, shorter mothers also had lower weight children. Shorter maternal height is associated with a higher risk of childhood underweight in children up to five years of age (Özaltin *et al.* 2010). This relationship is likely due to prenatal growth restriction. The persistence of the positive relationship between mother's height and child weight up to at least age 10 in our sample indicates children do not catch-up after birth. A lack of catch-up growth in both weight and linear growth in children with shorter mothers is also found in other developing countries, such as in the Maya of Mexico (Varela-Silva *et al.* 2009). While it is difficult to quantify the relative effects of programming and a poor postnatal environment, it is likely that, via the in-utero environment, mothers in our sample who experienced growth deficits as children are passing these on to their children.

Natarbora children are taller than Ossu children; however, this difference was not explained by any difference in ecology.

Social ecology did differ between the two sites, namely that in Natarbora there are more pension recipients, more developed toilets, and a higher average dietary diversity than in Ossu. Furthermore, mountainous Ossu is located at a higher altitude (600–1000 m above sea level) than coastal Natarbora (5–50 m). Stature in some highland populations tends to be shorter than in lowland populations (Haas *et al.* 1982; Mueller *et al.* 2001). While none of these factors individually explain all growth differences, it may be that overall conditions in Natarbora are better than in Ossu.

Differences in child growth between the two subdistricts are at least partially attributed to differences in maternal stature. Mothers are taller in Natarbora, as are children. Either this growth difference is due to genetic differences between the two locations, or growth is strongly influenced by intergenerational effects. The population of Timor-Leste is genetically complex as a result of several waves of early human migration (Gomes *et al.* 2015) and more recent Portuguese colonisation and Indonesian occupation. The populations of Ossu and Natarbora speak different languages, indicating different ancestry; however, a recent study found no difference in genetic markers across language groups, indicating considerable admixture has occurred (Gomes *et al.* 2016). Thus it is unlikely that the growth differences between the subdistricts are purely due to genetics. Differences in stature between the two subdistricts may be the result of ecological differences, but differences that have disappeared since the maternal generation. Better conditions in Natarbora than in Ossu during the mothers' childhoods would lead to shorter maternal stature in Ossu, which could then be passed to children via mechanisms described earlier. Thus, advancements in Timor-Leste's development may have narrowed present ecological differences between the two subdistricts, but differences in past conditions are still being expressed in children due to intergenerational effects on growth.

In this paper we have demonstrated that rural Timorese households show substantial variation in livelihood strategies in response to a transitioning economy. The more successful households are those with stable non-farm income sources. Their success is reflected in the ability to accumulate wealth and, in the case of salaried households, better long-term child growth. However, even within wealthier households, children fall well below international growth standards. The strength of the effect of maternal stature on both height and weight indicates that there are intergenerational influences on growth, and that household ecology and resource acquisition are secondary to the effects of early-life programming on current children's growth. The limited relationship between current household practices and child growth suggests that there is no 'best' livelihood strategy for households in this population. Thus, this study highlights the challenges of translating early-stage economic development in rural areas to improved child nutritional outcomes.

Acknowledgements This research was undertaken with the permission of the Ministry of Health, Timor-Leste. Thank you to the participating families from Ossu and Natarbora, and to the health clinics and local leaders for their support. We thank our local research assistants, Raimundo da Costa and Dedi Wibowo, for their invaluable contributions to this project. Human Ethics approval was granted by the University of Western Australia (RA/4/1/2401) and the Ministry of Health, Timor-Leste.

Funding The study was funded by the Australian Research Council (DP 120101588 to Debra Judge *et al.*), and by the School of Human Sciences, University of Western Australia.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

References

Akresh, R. (2009). Flexibility of household structure child fostering decisions in Burkina Faso. Journal of Human Resources 44(4): 976–997.

Andersen, A., Pant, J., and Thilsted, S. (2013). Food and nutrition security in Timor-Leste. Australian Centre for Agricultural Research, Penang, Malaysia.

Arimond, M., and Ruel, M. T. (2004). Dietary diversity is associated with child nutritional status: Evidence from 11 demographic and health surveys. The Journal of Nutrition 134(10): 2579–2585.

Barrett, C. B., Reardon, T., and Webb, P. (2001). Nonfarm income diversification and household livelihood strategies in rural Africa: Concepts, dynamics, and policy implications. Food Policy 26(4): 315–331.

Bateson, P., Barker, D., Clutton-Brock, T., Deb, D., D'Udine, B., Foley, R. A., Gluckman, P., Godfrey, K., Kirkwood, T., Lahr, M. M., McNamara, J., Metcalfe, N. B., Monaghan, P., Spencer, H. G., and Sultan, S. E. (2004). Developmental plasticity and human health. Nature 430(6998): 419–421.

Bettencourt, E. M. V., Tilman, M., de Sousa, H. P. D., Narciso, V., and da Silva, C. M. L. (2013). The economic and sociocultural role of livestock in the wellbeing of rural communities of Timor-Leste, University of Evora, CEFAGE-UE (Portugal).

Bongestabs, A. F. (2016). Universal old-age and disability pensions: Timor-Leste, International Labour Office Social Protection Department, Geneva.

Bouis, H. E., and Haddad, L. J. (1990). Effects of agricultural commercialization on land tenure, household resource allocation, and nutrition in the Philippines. International food policy research institute, Washington, DC.

Burnham, K. P., Anderson, D. R., and Huyvaert, K. P. (2011). AIC model selection and multimodel inference in behavioral ecology: Some background, observations, and comparisons. Behavioral Ecology and Sociobiology 65(1): 23–35.

Carletto, C., Corral, P., and Guelfi, A. (2017). Agricultural commercialization and nutrition revisited: Empirical evidence from three African countries. Food Policy 67(Supplement C): 106–118.

Christian, P., Lee, S. E., Donahue Angel, M., Adair, L. S., Arifeen, S. E., Ashorn, P., Barros, F. C., Fall, C. H. D., Fawzi, W. W., Hao, W., Hu, G., Humphrey, J. H., Huybregts, L., Joglekar, C. V., Kariuki, S. K., Kolsteren, P., Krishnaveni, G. V., Liu, E., Martorell, R., Osrin, D., Persson, L., Ramakrishnan, U., Richter, L., Roberfroid, D., Sania, A., ter Kuile, F. O., Tielsch, J., Victora, C. G., Yajnik, C. S., Yan, H., Zeng, L., and Black, R. E. (2013). Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low- and middle-income countries. International Journal of Epidemiology 42(5): 1340–1355.

Cramb, R. A., Colfer, C. J. P., Dressler, W., Laungaramsri, P., Le, Q. T., Mulyoutami, E., Peluso, N. L., and Wadley, R. L. (2009). Swidden transformations and rural livelihoods in Southeast Asia. Human Ecology 37(3): 323–346.

Crooks, D. L., Cliggett, L., and Cole, S. M. (2007). Child growth as a measure of livelihood security: The case of the Gwembe Tonga. American Journal of Human Biology 19(5): 669–675.

de Onis, M, Onyango, AW, Van den Broeck, J, Chumlea, WC & Martorell, R 2004, 'Measurement and standardization protocols for anthropometry used in the construction of a new international growth reference', Food and Nutrition Bulletin, vol. 25, no. Suppl. 1, pp. 27–36.

Deen, J., da Conceicao Matos, L., Temple, B., Su, J.-Y., da Silva, J., Liberato, S., da Silva, V., Soares, A. I., Joshi, V., Moon, S., Tulloch, J., Martins, J., and Mulholland, K. (2013). Identifying national health research priorities in Timor-Leste through a scoping review of existing health data. Health Research Policy and Systems 11(8). https://doi.org/10.1186/1478-4505-11-8.

Duflo, E. (2000). Child health and household resources in South Africa: Evidence from the old age pension program. The American Economic Review 90(2): 393–398.

Fernandes, R. (2015). Assessing the *Bolsa da Mãe* benefit structure, Social Protection & Labor, The World Bank.

Gomes, S. M., Bodner, M., Souto, L., Zimmermann, B., Huber, G., Strobl, C., Röck, A. W., Achilli, A., Olivieri, A., Torroni, A., Côrte-Real, F., and Parson, W. (2015). Human settlement history between Sunda and Sahul: A focus on East Timor (Timor-Leste) and the Pleistocenic mtDNA diversity. BMC Genomics 16: 70. https://doi.org/10.1186/s12864-014-1201-x.

Gomes, S. M., van Oven, M., Souto, L., Morreira, H., Brauer, S., Bodner, M., Zimmermann, B., Huber, G., Strobl, C., and Röck, A. W. (2016). Lack of gene–language correlation due to reciprocal female but directional male admixture in Austronesians and non-Austronesians of East Timor. European Journal of Human Genetics 25: 246–252.

Guerrant, R. L., Oriá, R. B., Moore, S. R., Oriá, M. O. B., and Lima, A. A. M. (2008). Malnutrition as an enteric infectious disease with long-term effects on child development. Nutrition Reviews 66(9): 487–505.

Haas, J. D., Moreno-Black, G., Frongillo, E. A., Pabon, A. J., Pareja, L. G., Ybarnegaray, U. J., and Hurtado, G. L. (1982). Altitude and infant growth in Bolivia: A longitudinal study. American Journal of Physical Anthropology 59(3): 251–262.

Herforth, A. (2010). Promotion of traditional African vegetables in Kenya and Tanzania: A case study of an intervention representing emerging imperatives in global nutrition, Cornell University, Doctoral dissertation.

Hong, R., Banta, J. E., and Betancourt, J. A. (2006). Relationship between household wealth inequality and chronic childhood undernutrition in Bangladesh. International Journal for Equity in Health 5(15). https://doi.org/10.1186/1475-9276-5-15.

Humphrey, J. H. (2009). Child undernutrition, tropical enteropathy, toilets, and handwashing. The Lancet 374(9694): 1032–1035.

Jones, A. D., Shrinivas, A., and Bezner-Kerr, R. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. Food Policy 46(Supplement C): 1–12.

Judge D. S., Sanders K. A., Reghupathy N., Amaral P. C., and Schmitt L. H. (2012). Family influences on long-term and short-term child growth in Ossu area, Timor-Leste. In Communicating New Research on Timor-Leste. Eds. M. Leach, N. C. Mendes, A. B. da Silva, B. Boughton and A. da Costa Ximenes. Timor-Leste Studies Association, Dili, Timor-Leste.

Kaiser, H. F. (1958). The varimax criterion for analytic rotation in factor analysis. Psychometrika 23(3): 187–200.

Kennedy, E., and Peters, P. (1992). Household food security and child nutrition: The interaction of income and gender of household head. World Development 20(8): 1077–1085.

Kent L., and Wallis J. (2013). Timor-Leste's veterans' pension scheme: Who are the beneficiaries and who is missing out?, Australian National University (state, Society & Governance in Melanesia), Canberra.

Kramer, K. L. (2005). Children's help and the pace of reproduction: Cooperative breeding in humans. Evolutionary Anthropology: Issues, News, and Reviews 14(6): 224–237.

Michael, H. (2006). Drinking-water quality assessment and treatment in East Timor. Dissertation for bachelor of environmental engineering. In The University of Western Australia.

Ministry of Finance (2010). Suco reports: Census. Dili, Timor-Leste. https://www.mof.gov.tl/about-the-ministry/statistics-indicators/sensus-fo-fila-fali/

Mofya-Mukuka, R., and Kuhlgatz, C. (2016). Impact of agricultural diversification and commercialization on child nutrition in Zambia: A dose response analysis. Journal of Agricultural Science 8(4): 60–75.

Molyneux, N., Da Cruz, G. R., Williams, R. L., Andersen, R., and Turner, N. C. (2012). Climate change and population growth in Timor Leste: Implications for food security. Ambio 41(8): 823–840.

Montgomery, M. A., and Elimelech, M. (2007). Water and sanitation in developing countries: Including health in the equation. Environmental Science & Technology 41(1): 17–24.

Motarjemi, Y., Käferstein, F., Moy, G., and Quevedo, F. (1993). Contaminated weaning food: A major risk factor for diarrhoea and associated malnutrition. Bulletin of the World Health Organization 71(1): 79–92.

Mueller, I., Vounatsou, P., Allen, B., and Smith, T. (2001). Spatial patterns of child growth in Papua New Guinea and their relation to environment, diet, socio-economic status and subsistence activities. Annals of Human Biology 28(3): 263–280.

Ngure, F. M., Humphrey, J. H., Mbuya, M. N. N., Majo, F., Mutasa, K., Govha, M., Mazarura, E., Chasekwa, B., Prendergast, A. J., Curtis, V., Boor, K. J., and Stoltzfus, R. J. (2013). Formative research on hygiene behaviors and geophagy among infants and young children and implications of exposure to fecal bacteria. The American Journal of Tropical Medicine and Hygiene 89(4): 709–716.

Ngure, F. M., Reid, B. M., Humphrey, J. H., Mbuya, M. N., Pelto, G., and Stoltzfus, R. J. (2014). Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: Making the links. Annals of the New York Academy of Sciences 1308(1): 118–128.

Özaltin, E., Hill, K., and Subramanian, S. (2010). Association of maternal stature with offspring mortality, underweight, and stunting in low-to middle-income countries. Journal of the American Medical Association 303(15): 1507–1516.

Pellegrini, L., and Tasciotti, L. (2014). Crop diversification, dietary diversity and agricultural income: Empirical evidence from eight developing countries. Canadian Journal of Development Studies 35(2): 211–227.

Pingali, P. L., and Rosegrant, M. W. (1995). Agricultural commercialization and diversification: Processes and policies. Food Policy 20(3): 171–185.

Reardon, T., Stamoulis, K., Balisacan, A., Cruz, M., Berdegué, J., and Banks, B. (1998). Rural non-farm income in developing countries. Special chapter in The State of Food and Agriculture 1998, Food and Agricultural Organization of the United Nations, Rome.

Reghupathy, N., Judge, D. S., Sanders, K. A., Amaral, P. C., and Schmitt, L. H. (2012). Child size and household characteristics in rural Timor-Leste. American Journal of Human Biology 24(1): 35–41.

Rola-Rubzen, M. F., Janes, J., Correia, V., and Dias, F. (2010). Challenges and constraints in production and marketing horticultural products in Timor Leste, III International Symposium on Improving the Performance of Supply Chains in the Transitional Economies, Kuala Lumpur, Malaysia, pp. 245–253.

Ruel, M. T. (2003). Is dietary diversity an indicator of food security or dietary quality? A review of measurement issues and research needs. Food and Nutrition Bulletin 24(2): 231–232.

Sanders K. A., Judge D. S., Pauli N., Amaral P. C., and Schmitt L. H. (2014). The influence of sex, age and season on child growth in Ossu sub-district, Timor Leste, 2009–2012. In Understanding Timor-Leste 2013. Eds. H. Loney, A. da Silva, N. Mendes, A. da Costa Ximenes and Fernandes C., Swinburne Press. 190–198.

Schmidt, M. K., Muslimatun, S., West, C. E., Schultink, W., Gross, R., and Hautvast, J. G. A. J. (2002). Nutritional status and linear growth of Indonesian infants in West Java are determined more by prenatal environment than by postnatal factors. The Journal of Nutrition 132(8): 2202–2207.

Silventoinen, K., Sammalisto, S., Perola, M., Boomsma, D. I., Cornes, B. K., Davis, C., Dunkel, L., de Lange, M., Harris, J. R., Hjelmborg, J. V. B., Luciano, M., Martin, N. G., Mortensen, J., Listicò, L., Pedersen, N. L., Skytthe, A., Spector, T. D., Stazi, M. A., Willemsen, G., and Kaprio, J. (2003). Heritability of adult body height: A comparative study of twin cohorts in eight countries. Twin Research 6(5): 399–408.

Spencer, P. R., Sanders, K. A., Canisio, A. P., and Judge, D. S. (2017). Household resources and seasonal patterns of child growth in rural Timor-Leste. American Journal of Human Biology 29(e22916). https://doi.org/10.1002/ajhb.22916.

Spencer, P. R., Sanders, K. A., and Judge, D. S. (2018). Growth curves and the international standard: How children's growth reflects challenging conditions in rural Timor-Leste. American Journal of Physical Anthropology 165(2): 286–298.

Steyn, N., Nel, J., Nantel, G., Kennedy, G., and Labadarios, D. (2006). Food variety and dietary diversity scores in children: Are they good indicators of dietary adequacy? Public Health Nutrition 9(5): 644–650.

Thu, P. M., and Judge, D. S. (2017). Household agricultural activities and child growth: Evidence from rural Timor-Leste. Geographical Research 55(2): 144–155.

Ulijaszek, S. J. (1995). Energy, effort and subsistence, In Human Energetics in Biological Anthropology. Cambridge University Press, Cambridge, pp. 151–165.

Varela-Silva, M. I., Azcorra, H., Dickinson, F., Bogin, B., and Frisancho, A. R. (2009). Influence of maternal stature, pregnancy age, and infant birth weight on growth during childhood in Yucatan, Mexico: A test of the intergenerational effects hypothesis. American Journal of Human Biology 21(5): 657–663.

von Braun, J. (1995). Agricultural commercialization: Impacts on income and nutrition and implications for policy. Food Policy 20(3): 187–202.

Waldron S., de Paulo Correia V., Mulik M., de Rego A., da Costa Varela C., Fordyce G., Thorne-George E., Dalgliesh N., Quigley S., and van de Fliert E. (2016). Sub-sector analysis of the Timor-Leste beef industry, report for ACIAR project LPS-2009-036. Australian Centre for International Agricultural Research.

Wu, G., Bazer, F. W., Cudd, T. A., Meininger, C. J., and Spencer, T. E. (2004). Maternal nutrition and fetal development. The Journal of Nutrition 134(9): 2169–2172.