# Longitudinal analyses of growth trajectories of rural East Timorese children aged 0-5 years

Phoebe Spencer, Ph.D, Lecturer,
School of Human Sciences, University of Western Australia
phoebe.spencer@uwa.edu.au
Debra S Judge, Ph.D,
Assoc Professor, School of Human Sciences, UWA
debra.judge@uwa.edu.au
with UNICEF-Dili

## Executive Summary

Child growth in rural Timor-Leste continues to be poor despite national development. Using data taken from a large, longitudinal study, this report examines the growth trajectories of 129 children in two rural areas of Timor-Leste measured at least five times before age 5. We aimed to identify any relationship between wasting and stunting, to identify whether growth trajectories change over a child's first 5 years, and to investigate the role of seasonality on growth trajectories. The prevalence of wasting in this population ranged from 8.5% to 13.2%, whereas stunting affected approximately 50% of children at each follow up. We found no relationship between wasting and stunting, but a strong relationship between underweight and stunting, where stunted children are more likely to be also underweight. Wasting is not a useful indicator of child growth in this population. A majority of children in this population have growth trajectories that change in and out of categories indicating stunting or underweight. However, sustained recovery from stunting or underweight is rare because conditions in these children's environment are relatively poor. Only 10% of children were able to recover from stunting and maintain that recovery, and only 14.3% of children recovered from baseline underweight and maintained recovery. Seasonal changes in food availability are a significant ecological pressure in this population. Seasonality affects WAZ in older children, and could contribute to age-related declines in growth outcomes. We recommend targeting interventions as close to birth as possible to maximise the chance of sustained recovery from stunting and underweight, also suggest timing nutritional interventions with the food-scarce rainy season.

Introduction

Poor anthropometric scores indicative of poor health and nutrition of children persist in Timor-Leste (General Directorate of Statistics et al. 2018). The vast majority of studies into child growth in Timor-Leste are cross-sectional (for example the Demographic and Health Survey) and thus findings can be influenced by cohort characteristics in a rapidly changing environment. This report relies on data from a longitudinal study of rural children in two regions that allows us to ask specific questions about patterns of growth trajectories. By examining growth from a longitudinal perspective, we aim to better understand how growth deficits present in the first five years of life. Specifically, we aim to determine:

1) the relationship between wasting and stunting both synchronically and heterochronically,
2) whether children's growth trajectories can change, for example, recover from stunting, and
3) how seasonally varying food availability affects growth trajectories in the first five years.

Characteristics of the sample

This study is based in two rural areas in Timor-Leste – the Ossu sub-district of the Viqueque municipality in the mountains of the central east (600-1000m above sea level), and the Natarbora sub-district of the Manatuto district in the flat coastal plains of the south (5-50m above sea level). Data were collected over a ten-year period from 2009-2019 as part of a larger, longitudinal study of family ecology and children's growth. Ossu was first visited in 2009, and Natarbora in 2012. Both sub-districts' samples include four local communities with varying distances to community amenities. Subjects were recruited through approaching households on a nearest neighbour basis, and gaining consent from households with resident children (under 19 years; Reghupathy et al. 2012; Thu & Judge 2017). Households were then re-visited on a six-monthly to yearly basis, with some additional recruitment of participants each year. At all visits, participating children were measured for height, weight, mid-upper arm circumference and head circumference (for children under ~7 years of age; de Onis et al. 2004), and resulting measures were converted to z-scores where standardisations are available (World Health Organization 2006). Indicators of nutritional status were then calculated from z-scores. Stunting and underweight are defined as ≥ 2 standard deviations below the international median for height-for-age and weight-for-age, respectively; wasting is defined as ≥ 2 standard deviations below the international median for weight-for-height (WHO 2010).

This study uses an age-restricted subset of the larger, longitudinal database. Herein, children were included if they were measured for both height and weight on at least 5 occasions between birth and age 5 years (n = 129 children; Table 1). A small number of children (n = 27) were measured 7 times during the same period. Due to the rolling nature of recruitment to this study, baseline measurements for children occurred between 2009 and 2016. Mean age at baseline was 11.6 months (Figure 1). Of the included children, 53 were from Ossu and 76 were from Natarbora. The sample included 58 girls (Table 2) and 71 boys (Table 3). Some households had more than one child in this sample; children were from a total of 94 households.

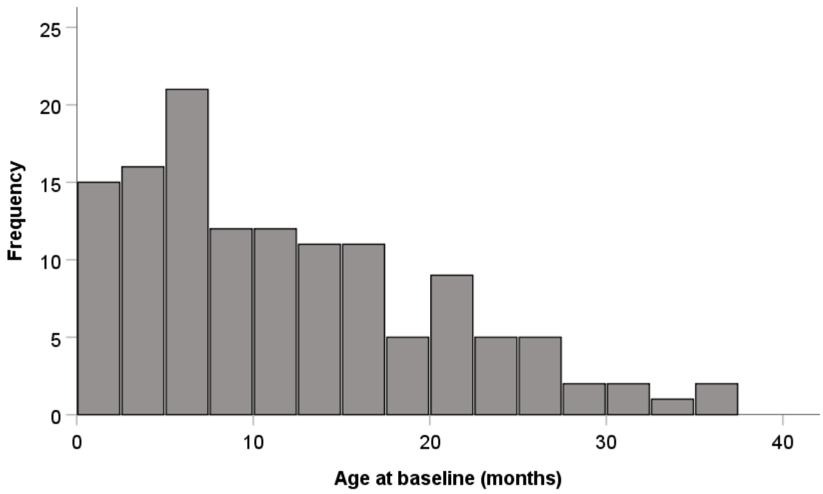



Figure 1: Child age (months) at baseline for 129 children; $\bar{x}$ = 11.6 months, SD = 8.5. The preclusion of children of older ages at baseline results from the inclusion criteria of at least 5 measurement events.

Rural populations in Timor-Leste experience a ‘hungry’ season during the wetter months (November to April) where food is scarce, and a ‘harvest’ season (May to October) of greater food availability. Each visit was therefore coded as occurring immediately following the hungry season, or during the harvest season.

Table 1: Mean age and overall measurement statistics for baseline and follow-up measures on **129 rural children** measured at least five times before age 5. Standardised height-for-age (HAZ), standardised weight-for-age (WAZ), and standardised weight-for-height (WHZ) are presented with standard deviations with percentages of children stunted, underweight, wasted, and both stunted and wasted.

| | n | Mean age (months) | Mean HAZ (SD) | % stunted | Mean WAZ (SD) | % underweight | Mean WHZ (SD) | % wasted | % both wasted & stunted |
|---|---|---|---|---|---|---|---|---|---|
| baseline | 129 | 11.59 (8.47) | -1.75 (1.68) | 46.5 | -1.10 (1.28) | 27.1 | 0.00 (1.57) | 8.5 | 3.1 |
| follow-up 1 | 129 | 20.98 (10.30) | -2.03 (1.41) | 56.3 | -1.47 (1.20) | 34.9 | -0.59 (1.48) | 12.4 | 3.9 |
| follow-up 2 | 129 | 29.17 (10.12) | -2.25 (1.29) | 60.5 | -1.71 (1.11) | 38.8 | -0.71 (1.32) | 13.2 | 8.5 |
| follow-up 3 | 129 | 37.39 (9.89) | -2.10 (1.27) | 55.8 | -1.71 (0.91) | 34.9 | -0.77 (0.93) | 8.5 | 3.9 |
| follow-up 4 | 129 | 45.41 (9.37) | -1.92 (1.19) | 55.0 | -1.74 (0.91) | 38.8 | -0.93 (0.99) | 12.4 | 6.2 |
| follow-up 5 | 68 | 50.28 (6.74) | -1.87 (1.10) | 50.0 | -1.68 (0.93) | 39.7 | -0.83 (0.93) | 10.3 | 5.9 |
| follow-up 6 | 27 | 54.07 (4.50) | -1.70 (0.93) | 40.7 | -1.71 (0.94) | 33.3 | -1.06 (0.89) | 11.1 | 11.1 |

Table 2: Mean age and overall measurement statistics for baseline and follow-up measures on **58 rural girls** measured at least five times before age 5.

| Girls | n | Mean age (months) | Mean HAZ (SD) | % stunted | Mean WAZ (SD) | % underweight | Mean WHZ (SD) | % wasted | % both wasted & stunted |
|---|---|---|---|---|---|---|---|---|---|
| baseline | 58 | 12.23 (9.08) | -1.86 (1.64) | 44.8 | -1.16 (1.20) | 25.9 | 0.04 (1.60) | 8.6 | 1.7 |
| follow-up 1 | 58 | 20.83 (10.29) | -2.07 (1.39) | 62.1 | -1.34 (1.17) | 24.1 | -0.30 (1.42) | 8.6 | 3.4 |
| follow-up 2 | 58 | 28.88 (10.10) | -2.34 (1.22) | 65.5 | -1.78 (0.90) | 37.9 | -0.67 (1.06) | 12.1 | 6.9 |
| follow-up 3 | 58 | 36.84 (9.78) | -2.17 (1.26) | 62.1 | -1.68 (0.78) | 36.2 | -0.60 (0.84) | 3.4 | 0.0 |
| follow-up 4 | 58 | 45.24 (9.07) | -2.08 (1.09) | 60.3 | -1.78 (0.90) | 37.9 | -0.78 (0.92) | 5.2 | 3.4 |
| follow-up 5 | 34 | 50.97 (5.47) | -2.00 (1.11) | 58.8 | -1.78 (0.84) | 44.1 | -0.83 (0.92) | 8.8 | 5.9 |
| follow-up 6 | 9 | 53.44 (4.77) | -1.70 (0.72) | 44.4 | -1.89 (0.66) | 33.3 | -1.26 (0.70) | 11.1 | 11.1 |

Table 3: Mean age and overall measurement statistics for baseline and follow-up measures on **71 rural boys** measured at least five times before age 5.

| Boys | n | Mean age (months) | Mean HAZ (SD) | % stunted | Mean WAZ (SD) | % underweight | Mean WHZ (SD) | % wasted | % both wasted & stunted |
|---|---|---|---|---|---|---|---|---|---|
| baseline | 71 | 11.06 (7.97) | -1.66 (1.71) | 47.9 | -1.06 (1.35) | 28.2 | -0.04 (1.56) | 8.5 | 4.3 |
| follow-up 1 | 71 | 21.1 (10.37) | -2.00 (1.43) | 51.4 | -1.57 (1.22) | 43.7 | -0.82 (1.50) | 15.5 | 9.9 |
| follow-up 2 | 71 | 29.41 (10.20) | -2.18 (1.36) | 56.3 | -1.64 (1.26) | 39.4 | -0.73 (1.50) | 14.1 | 7.0 |
| follow-up 3 | 71 | 37.83 (10.02) | -2.04 (1.29) | 50.7 | -1.74 (1.01) | 33.8 | -0.91 (0.99) | 12.7 | 8.5 |
| follow-up 4 | 71 | 45.55 (9.68) | -1.78 (1.26) | 50.7 | -1.71 (0.99) | 39.4 | -1.05 (1.04) | 18.3 | 5.9 |
| follow-up 5 | 34 | 49.59 (7.84) | -1.75 (1.09) | 41.2 | -1.57 (1.00) | 35.3 | -0.83 (0.95) | 11.8 | 11.1 |
| follow-up 6 | 18 | 54.39 (4.62) | -1.69 (1.03) | 38.9 | -1.62 (1.06) | 33.3 | -0.95 (0.97) | 11.1 | 11.1 |

For comparison with previous Demographic and Health Surveys, the prevalence of stunting, wasting and underweight by age group is presented in Table 4. Note that as this sample is longitudinal, examining the data in a cross-sectional manner means the same children are repeated across multiple age groups.

Table 4: Percentages of measurements classified as stunted, underweight and wasted by age group (months). n = 761 total measurements from 129 children. Individual children are measured over multiple ages.

| | | 0-5 mos | 6-11 mos | 12-23 mos | 24-35 mos | 36-47 mos | 48-60 mos | Overall (x %) |
|---|---|---|---|---|---|---|---|---|
| HAZ | % stunted | 33.3 | 41.0 | 65.4 | 66.9 | 50.6 | 46.6 | 54.5 |
| WAZ | % underweight | 17.8 | 18.0 | 35.3 | 38.6 | 36.0 | 39.1 | 34.6 |
| WHZ | % wasted | 6.7 | 6.6 | 17.3 | 7.2 | 9.9 | 10.6 | 10.5 |

Characteristics of children at baseline

We investigated if certain child characteristics were associated with the presence of stunting, underweight and wasting at baseline (Table 5). In all previous work (using cross-sectional data with children up to 19 years), boys exhibit consistently poorer growth than do girls, Ossu children have poorer growth than Natarbora children, and weight-for-age varies by season (Spencer et al. 2017; Sanders et al. 2014; Spencer et al. 2018b). Clearly using the categorizations of stunted, underweight, and wasted are a blunter instrument for understanding variation than the analyses of actual Z scores. This report narrows the focus to a longitudinal subsample of children aged <5 years, and examining characteristics at baseline further narrows the scope to children <2 years and looks more specifically at the identification of stunting, underweight, and wasting. Of sex, site, season of baseline and age, only age was significantly associated with stunting, underweight and/or wasting. Stunted children were on average 4.3 months older than non-stunted children, and underweight children were on average 4.9 months older than non-underweight children. We know that in this rural population, standardised growth declines with age – that is, relative to international norms, average values decline as children get older (Spencer et al. 2018a). The analysis presented herein demonstrates that the negative relationship between child age and growth is evident even within the 0-2 years age bracket, as children who exhibited stunting, underweight or wasting at baseline were, on average, older than those who did not. We also know that growth in the first two years of life is a strong predictor of later life growth (Spencer et al. in prep). In this sample, *the proportions of children exhibiting stunting, underweight, and wasting increase most precipitously in the second year of life.* This means *that interventions should be targeted as close to 1 year of age as possible to minimise the likelihood that children incur growth deficits.*

Table 5: Children's experience of stunting, underweight and wasting at baseline by child and local environmental characteristics. Numbers of cases and percent of total in comparison set are presented; p values result from Chi-square tests except for age (independent samples t-test). Significant p values (<.05) are shown in bold.

| | | **Stunted** | | | **Underweight** | | | **Wasted** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Yes (% of total) | No (%) | p | Yes (% of total) | No (%) | p | Yes (% of total) | No (%) | p |
| **Sex** | Girls | 26 (20.2) | 32 (24.8) | .729 | 15 (11.6) | 43 (33.3) | .769 | 5 (3.9) | 65 (50.4) | .973 |
| | Boys | 34 (26.3) | 37 (28.7) | | 20 (15.5) | 51 (39.5) | | 6 (4.7) | 53 (41.0) | |
| **Site** | Natarbora | 31 (24.0) | 45 (34.9) | .119 | 16 (12.4) | 60 (46.5) | .063 | 6 (4.7) | 70 (54.3) | .758 |
| | Ossu | 29 (22.5) | 24 (18.6) | | 19 (14.7) | 34 (26.3) | | 5 (3.9) | 48 (37.2) | |
| **Season** | Hungry | 17 (13.2) | 18 (14.0) | .775 | 10 (7.6) | 25 (19.4) | .822 | 3 (2.3) | 32 (24.8) | .991 |
| | Harvest | 43 (33.3) | 51 (39.5) | | 25 (19.4) | 69 (53.4) | | 8 (6.2) | 86 (66.7) | |
| **Age** | Mean age at baseline in months (SD) | 13.9 (8.6) | 9.6 (7.9) | **.004** | 15.1 (9.5) | 10.3 (7.7) | **.003** | 12.9 (8.7) | 11.5 (8.5) | .589 |

The relationship between wasting and stunting

We investigated whether children who experience wasting are likely to become stunted, or whether children who are wasted are more likely to become stunted. Approximately half of participating children were stunted at each time point. The prevalence of wasting in this population ranged from 8.5% to 13.2% (Table 1) – between the poor and serious cut-offs for public health significance (WHO 2010).

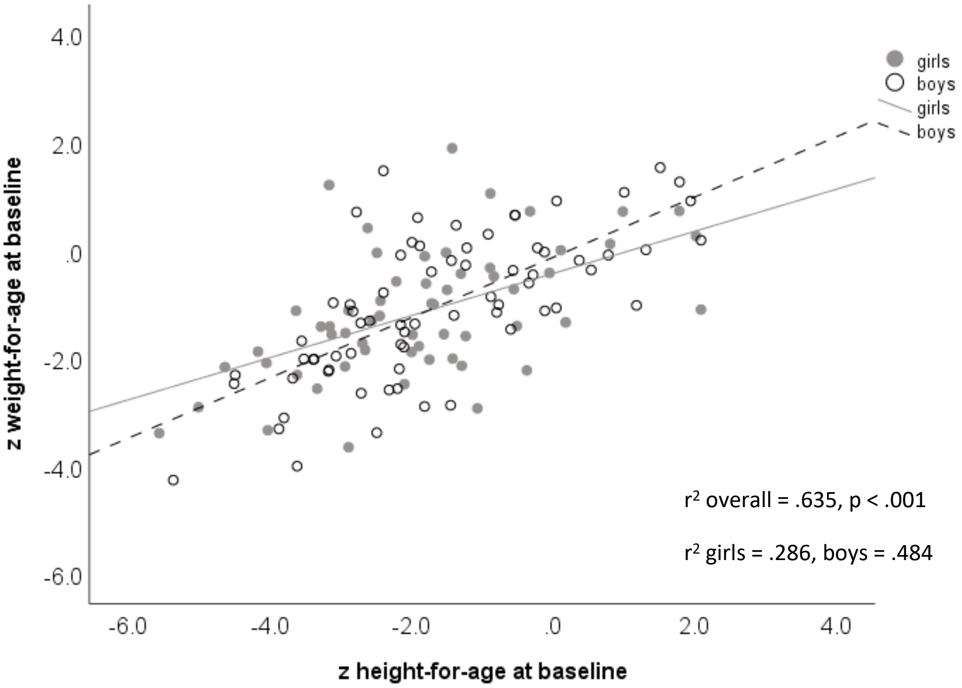
Children who were wasted at any visit were neither more nor less likely to be stunted at any visit (the same visit or subsequent visits) than children who were not wasted. We tested every combination of the two conditions at every time point. For example, wasting at baseline was not associated with stunting at baseline ($\chi^2_{(1)}$ = .498, p = .480), or follow-up 1 ($\chi^2_{(1)}$ = .077, p = .074), or follow-up 2 ($\chi^2_{(1)}$ = 2.294, p = .130), etc. Similarly, *stunting at any time point did not predict wasting at any subsequent time point.*

To examine this relationship in more detail, we compared the mean HAZ of children who experienced wasting with the HAZ of children who were not wasted. Children who were wasted at baseline were not shorter for age ($\bar{x}$ HAZ = -1.27) at baseline than children who were not wasted ($\bar{x}$ HAZ = -1.80; independent samples t = -1.00; p = .316). Mean HAZ did not differ at any subsequent follow-up relative to a child's experience of wasting at baseline. Children who were wasted at follow-up 1 (n = 16) had higher HAZ ($\bar{x}$ = -1.30) at follow-up 1 than their non-wasted counterparts wasted ($\bar{x}$ = -2.13; independent samples t = -2.17; p = .032); however, this relationship did not persist to other time points. Because wasting is defined as weight-for-height, children whose linear growth is lower are less likely to fit the classification for wasting. As *a significant proportion of children in this population have poor linear growth (HAZ), using wasting as an indicator underestimates the proportion of children experiencing poor growth.*

We also investigated the relationship between underweight and stunting. Unlike with wasting, there was a relationship between underweight and stunting.. At baseline, children who were stunted were also likely to be underweight ($\chi^2_{(1)}$ = 21.652, p < .001), and also to be underweight at all subsequent time points. Similarly*, being underweight at baseline was associated with stunting at all follow-ups.*

Thus, children in this population who have growth deficits tend to grow poorly in both height and weight from early in life (Figure 2A). WAZ and HAZ continue to have a positive relationship at subsequent follow-ups (Figure 2B & C). As a result, while wasting is a good predictor of child mortality, *wasting is not a useful indicator of persistent malnutrition as children are short AND underweight rather than underweight for their height. Furthermore, both stunting and underweight provide similar information about a child's future growth, as the two measures are closely associated.*

A)


4.0
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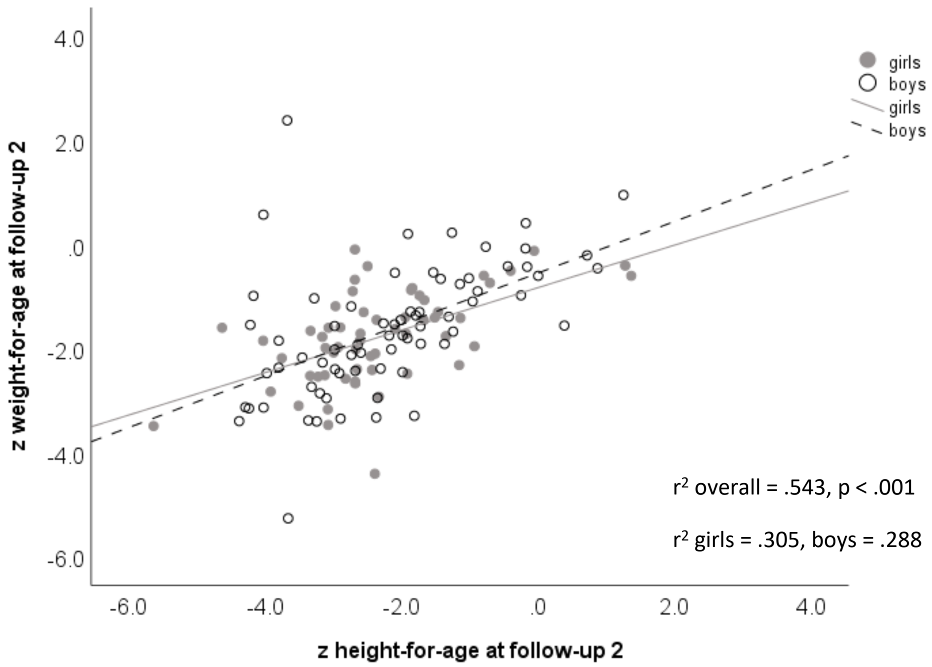
girls
boys
girls
boys
r² overall = .635, p < .001
r² girls = .286, boys = .484

B)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z weight-for-age at follow-up 2
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2.0
4.0
z height-for-age at follow-up 2
girls
boys
girls
boys
r² overall = .543, p < .001
r² girls = .305, boys = .288

C)

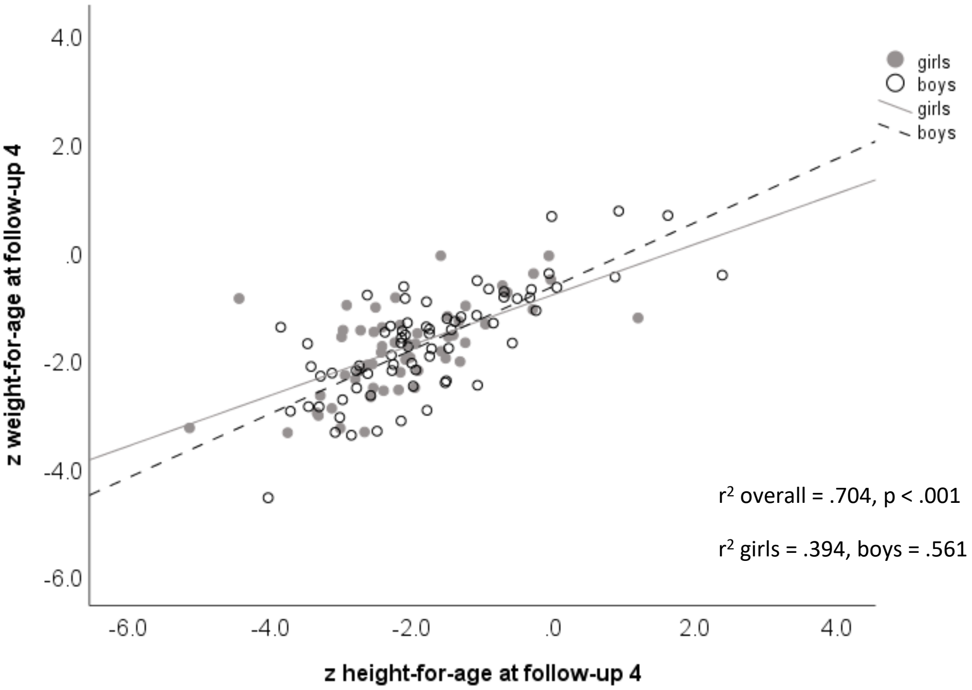



Figure 2: The simultaneous association between WAZ and HAZ at baseline (A), at follow-up 2 (B) and at follow-up 4 (C).

<u>Can growth trajectories change?</u>

To identify potential target groups for intervention, we investigated whether some children show a greater capacity to change their growth trajectories than others. We classified children according to the longitudinal nature of their growth, that is, their experience of stunting or underweight across follow-ups (Table 6). For stunting, children were classified as 'never stunted' if they did not exhibit stunting at any visit, 'always stunted' if they were stunted at every visit, and 'change' if their HAZ was not consistently stunted or consistently normal. The same categories were used for underweight.

Table 6: Longitudinal growth category of 129 children for stunting and underweight. 'Never' = never experience the condition, 'always' = experience the condition at every follow-up, 'change' = experience the condition at some follow-ups but not others.

| Category | Stunting (% of children) | Underweight (% of children) |
|---|---|---|
| Never | 20.9 | 42.6 |
| Always | 27.1 | 15.5 |
| Change | 51.9 | 41.9 |

In order to determine factors that may contribute to consistently good or consistently poor growth, we compared characteristics of the 'never' and 'always' categories with regards to sex, age, site and season of measurement. 'Change' children were excluded from this analysis. Despite boys consistently showing poorer growth than girls in this population (Reghupathy et al. 2012; Spencer et al. 2018a), in this longitudinal subsample, approximately equal numbers of boys and girls fell into each category for both stunting ($\chi^2_{(1)} = .699$, $p = .403$) and underweight ($\chi^2_{(1)} = .897$, $p = .344$). Ossu children were more likely than Natarbora children to ever experience stunting, and Ossu children were more likely to be always stunted ($\chi^2_{(1)} = 14.448$, $p < .001$), with the same pattern occurring for underweight ($\chi^2_{(1)} = 6.300$, $p = .012$). Thus, *variations in broader ecological influences across rural Timor-Leste contribute to growth patterns in children* (Spencer et al. 2018b; Spencer et al. 2017). Age at baseline was not significantly related to stunting category (independent samples $t = -.630$; $p = .531$) or underweight category (independent samples $t = -1.782$; $p = .079$). The season of the baseline measurement did not relate to stunting ($\chi^2_{(1)} = .840$, $p = .359$) or underweight category ($\chi^2_{(1)} = .652$, $p = .419$) at baseline.

What are the characteristics of children with inconsistent growth trajectories?

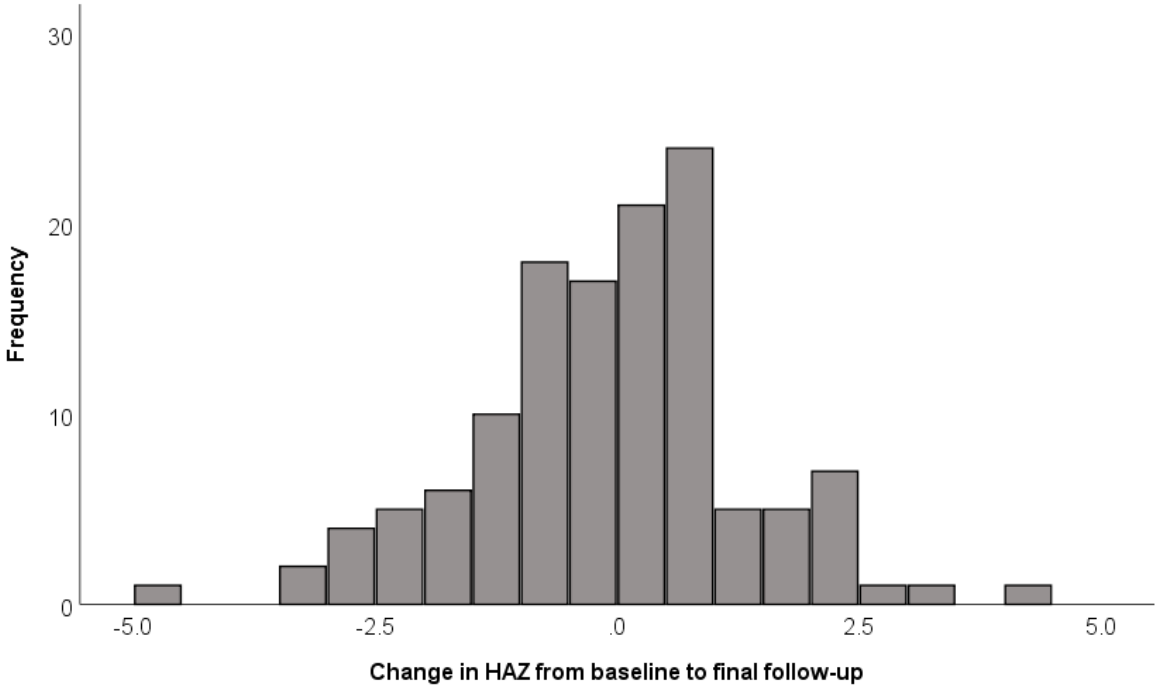
Approximately half of the children in the sample changed from being stunted to not stunted, or vice versa, over the study period. Of those who were stunted at baseline (n = 60), 15 (25%) recovered by follow-up 1 (FU1), but seven of these are stunted again by follow-up 2 (FU2). Only six children (10%) who were stunted at baseline recovered by follow-up 1 and maintained recovery. Two recovered permanently at FU2, four at FU3 and two at FU4. Fourteen children who were stunted at baseline showed sustained recovery – i.e. change category then remain 'normal' up to and including the final follow-up. Thus, *change across follow-ups in HAZ is common and complete recovery is rare*.

*Recovery from underweight was less common*. Of the 35 children who were underweight at baseline, 20 (57%) remained underweight for the entire follow-up period. Only five children (14%) recovered from being underweight at baseline and sustained that recovery.

To better understand the way children's growth changes over the first five years of life, we calculated the change in z score between baseline and final follow-up (final z score – baseline z score; Figure 2). The change in z score indicates the overall direction of the child's growth trajectory; for example, a positive value indicates the child's growth improved from baseline to final follow-up. Then, to examine the consistency of the growth trajectory, we calculated the cumulative change in z scores from baseline through follow-up 5 (Figure 3). This metric is the sum of the absolute values of each change, i.e. baseline to FU1 + FU1 to FU2 + … *A smaller value indicates the child grew on a tightly constrained trajectory, whereas a larger number indicates a greater degree of movement around a trajectory.* The calculation of cumulative change includes measures up to and including only follow-up 5, as including measures past follow-up 5 would inflate this value for those children who were measured more times before the age of 5.

On average, HAZ did not change across the follow-up period, and WAZ declined slightly (Table 6). *Despite children appearing to grow along the same trajectory from baseline to final follow-up, the average child accumulated more than two standard deviations in change (negative and/or positive) in both HAZ and WAZ over the follow-up period* (Table 7).

A)




B)

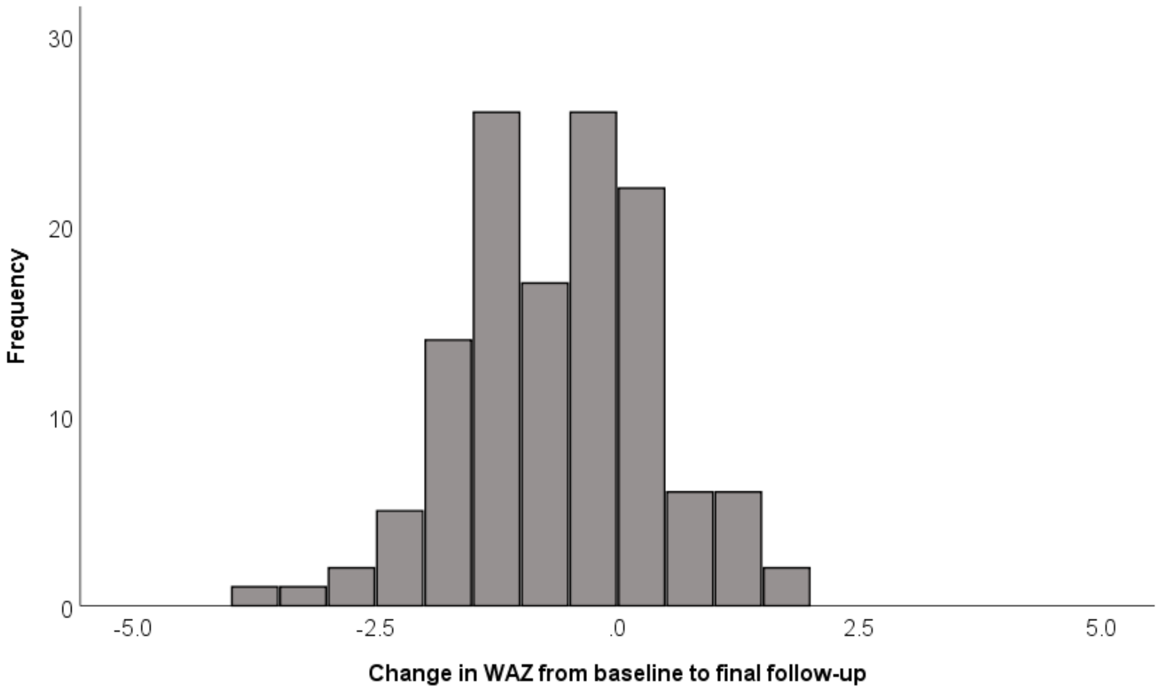
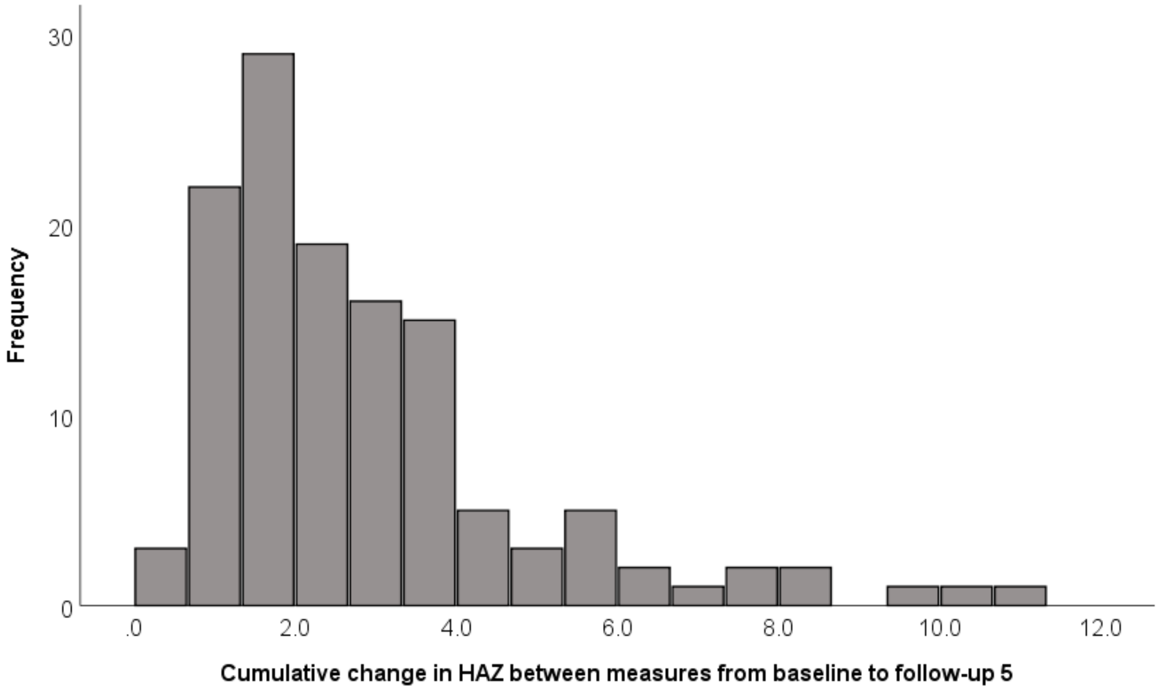



Figure 2: Change in z height-for-age (A) and z-weight-for-age (B) for 129 children comparing the final measurement to the baseline measurement (FU5-baseline). Values above zero indicate a net positive change in z score over the developmental period.

A)




B)

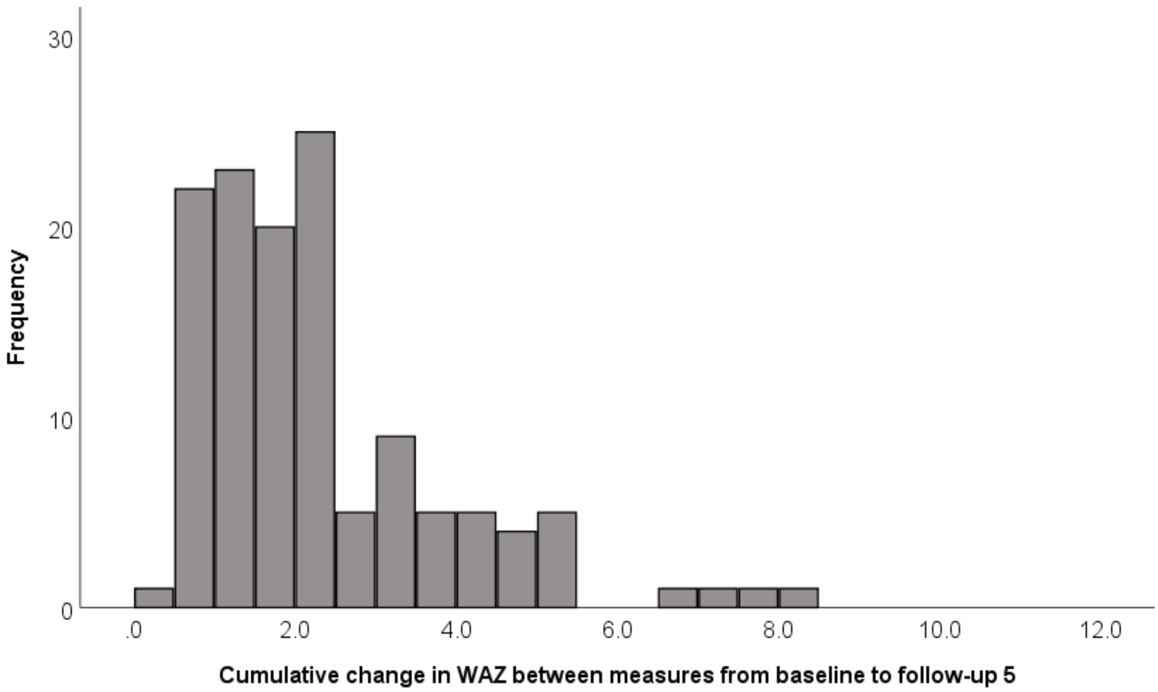



Figure 3: Cumulative change in z height-for-age between measurements (A) and z weight-for-age (B) for 129 children from baseline measurement up to and including follow-up 5. This metric sums all periodic change in z scores over all intervals irrespective of direction. Larger values indicate more fluctuations in the growth trajectory, but not necessarily more positive outcomes.

Table 7: Mean change (SD) and cumulative change in WAZ and HAZ scores across the follow-up period. Change is calculated to final follow up; absolute change to follow-up 5.

| | Mean (SD) |
|---|---|
| Change in WAZ (Final FU – baseline) | -.61 (1.03) |
| Change in HAZ (Final FU – baseline) | -.08 (1.42) |
| Cumulative sum of changes in WAZ baseline to follow-up 5 (absolute value) | 2.29 (1.55) |
| Cumulative sum of changes in HAZ baseline to follow-up 5 (absolute value) | 2.88 (2.05) |

We compared children who did not change in height (i.e. always stunted and never stunted; n = 62) with children who had fluctuating growth trajectories (n = 67). While the cumulative change in HAZ was different between the two groups (no change $\bar{x}$ = 2.16, change $\bar{x}$ = 3.56; independent samples t = -4.10; p < .001), the difference in z score from baseline to final follow-up (final follow up z score – baseline z score) did not differ between the groups (no change $\bar{x}$ = .07, change $\bar{x}$ = -.18; independent samples t = .967; p = .335). This indicates that while some children in this population show the capacity to change their growth trajectories significantly from visit to visit*, on average, both groups show little deviation from their starting z score at the final follow-up visit.*

We performed the same analysis of change (n = 54) vs. non-change children (n = 75) with weight-for-age. As with HAZ, and as expected, the cumulative change in WAZ was greater in the change group (no change $\bar{x}$ = 1.91, change $\bar{x}$ = 2.81; independent samples t = -3.40; p = .001). There was a trend (independent samples t = 1.78, p = .078) for the change children to have a greater decline in WAZ over the study period than the non-change children (no change $\bar{x}$ = -.47, change $\bar{x}$ = -.79). This indicates that *unlike HAZ, a change in underweight category is more likely a decline in WAZ than an improvement*. This fits with the *overall slight decline in WAZ experienced by the cohort from baseline to final follow-up*.

Only 21 (16.3%) children demonstrated a significant improvement in HAZ (change in z score ≥ 1) over the follow-ups, and only 8 (6.2%) demonstrated a significant improvement in WAZ. Thus, we compared children who demonstrated any growth improvement (change in HAZ or

WAZ > 0; n = 65 (50.4%) and 36 (27.9%), respectively) with children who did not improve. Boys and girls were equally likely to improve over the follow-up period (HAZ $\chi^2_{(1)}$ = .038, p = .846; WAZ $\chi^2_{(1)}$ = .074, p = .786), and children from Ossu or Natarbora were equally likely to improve (HAZ $\chi^2_{(1)}$ = 1.504, p = .220; WAZ $\chi^2_{(1)}$ = .904, p = .342).

This investigation into the nature of child growth trajectories reveals that both height and weight are labile in the first five years of life. As weight is a short-term measure of growth, we would expect children to experience movement around a growth trajectory as they respond to environmental conditions. Height, however, is a long-term, cumulative measure of growth, so we would predict less change in height z scores from visit to visit than in weight. Thus, the magnitude of change in HAZ that children in this population experience is unexpected, and indicates that height is also responsive to the environment rather than being tightly constrained around a genetically-determined trajectory. This finding has positive implications for interventions into stunting – as demonstrated by approximately half of this sample, children *can* experience substantial improvements in HAZ before the age of five. However, they are unable to sustain recovery in the natural environment, suggesting that intervention is required to permanently reverse stunting. For the 27.1% of children who were always stunted, it is possible that their growth also remains labile and able to recover, but requires a greater positive change in conditions than is present in the natural environment. It is also possible that these children's growth is influenced by events/conditions earlier than the current protocol can identify. We are unable to get birth weights for most children and so cannot identify children born prematurely or small for gestation, conditions associated with poorer childhood growth outcomes (Binkin et al. 1988).

<u>The effect of seasonality on growth changes</u>

Due to the timing of follow-ups relative to the agricultural cycle (described page 2), food availability may contribute to whether growth measures improve or decline from one follow-up ($T_i$) to the next ($T_{i+1}$). Previous cross-sectional and longitudinal research in this population indicates that mean WAZ is lower when measured immediately following the hungry season than later in the harvest season (Spencer et al. 2017; Sanders et al. 2014; Judge et al. 2012). To investigate the effect of season in this longitudinal, age-restricted subsample, we examined whether change in WAZ and HAZ between follow-ups differed depending on the season of the previous measure (Table 8). For example, if the mean change in WAZ from baseline ($T_i$) to follow-up 1 ($T_{i+1}$) differed depending on whether the baseline measurement occurred during the hungry season or the harvest season. The average time between follow-ups was 8.4 months. As each season spans approximately 6 months, this means that in the majority of cases, consecutive follow-ups occurred in different seasons, meaning change in z score could be attributed to seasonal change. However, in the case of longer intervals, children may have been measured in the harvest season of two subsequent years and thus the change in z score is influenced by multiple seasons. The inclusion of longer intervals thus may wash out any seasonal effects presented herein.

Table 8: Mean change in WAZ and HAZ for each measurement interval ($T_i$ to $T_{i+1}$) by the season of first time point of the interval ($T_i$; independent samples t-test). 'Harvest' is the season of relative food plenty, 'hungry' is the season of food scarcity. Significant values shown in bold ($p < .05$).

| Measurement interval ($T_i$ to $T_{i+1}$) | Season of $T_i$ (n) | Mean **change** in **WAZ** (SD) | t | p | Mean **change** in **HAZ** (SD) | t | p |
|---|---|---|---|---|---|---|---|
| Baseline to FU1 | Harvest (94) | -.36 (1.05) | -.019 | .985 | -.26 (1.40) | -.236 | .814 |
| | Hungry (35) | -.36 (1.20) | | | -.33 (1.44) | | |
| FU1 to FU2 | Harvest (90) | -.26 (1.06) | .335 | .738 | -.29 (1.31) | .961 | .338 |
| | Hungry (39) | -.19 (.86) | | | -.07 (82) | | |
| FU2 to FU3 | Harvest (100) | .01 (.73) | -.402 | .688 | .19 (.79) | -.920 | .359 |
| | Hungry (29) | -.05 (.42) | | | .03 (.97) | | |
| FU3 to FU4 | Harvest (85) | -.06 (.42) | 1.349 | .180 | .17 (.70) | .287 | .774 |
| | Hungry (44) | .04 (.31) | | | .20 (.53) | | |
| FU4 to FU5 | Harvest (52) | -.01 (.29) | 2.701 | **.009** | .09 (.57) | .831 | .409 |
| | Hungry (16) | .22 (.33) | | | .21 (.22) | | |

The only significant difference was found between follow-ups 4 and 5 in WAZ. WAZ is more likely than HAZ to respond to short-term changes in food availability. In later follow ups, when children are older, children whose $T_i$ measure was taken at the end of the hungry season were more likely to show improved WAZ at the subsequent measure ( $T_{i+1}$). At younger ages, breastfed children are buffered from food scarcity through the mother (Sellen 2007), whereas by follow-up 5 (mean age 4.2 years), most children are fully weaned and therefore experience the full effect of food seasonality. Another explanation is that slight seasonal changes in WAZ, while not significant at younger ages, accumulate to reach a significant effect by follow-up 5. The two explanations are not mutually exclusive.

<u>Conclusions</u>

To summarise, this report addressed three main aims: to identify any relationship between wasting and stunting, to identify whether growth trajectories change over a child's first 5 years, and to investigate the role of seasonality on growth trajectories.

With respect to the relationship between stunting and wasting, we found no relationship between wasting and stunting in these rural Timor-Leste children. This is because most children are both short and underweight for their age, rather than underweight for their height. Given that most children are short, those exhibiting wasting are the extremes of poor growth and in low numbers. Wasting is a good predictor of child mortality, but is not of sufficient resolution to identify chronic malnourishment. *Wasting is not a useful indicator of poor growth and malnutrition in this population – it only identifies the most extreme cases*. Similarly, *stunting at any time point did not predict wasting at any subsequent time point (nor did wasting did not predict future stunting).*

We found a close relationship between underweight and stunting, and between WAZ and HAZ, that begins early in life and persists over the first five years. Thus, *wasting should not be used as an indicator of poor growth as it will underestimate the prevalence of poor growth outcomes*. Either underweight or stunting identifies growth challenged children in this population as the conditions are closely linked.

Identifying if, and when, children's growth trajectories can change is important to the timing and expectations for improvements to growth with nutritional interventions over the first 5 years. Growth is labile over the first five years of life. A majority of children in this population have growth trajectories that shift them in and out of categories indicating stunting or underweight. While changes in growth patterns are common, sustained recovery from stunting or underweight is rare because conditions in these children's environment are relatively poor. Only 10 % of children were able to recover from stunting and maintain that recovery, and only 14.3% of children recovered from baseline underweight and maintained recovery.

Food seasonality is a significant ecological pressure across Timor-Leste. Previous work on the Ossu population of children from which part of this subsample derives indicated that average WAZ, Z-BMI and middle upper arm circumferences were depressed after the food scarce season (Judge et al. 2012). Spencer et al. (2017) reported significant declines in WAZ from the end of one harvest over a single rainy (food scarce/hungry) season. These patterns are exacerbated when climatic patterns such as La Niña events occur.

In this longitudinal sample of 0-5 year old children, seasonality only affects WAZ in the oldest children (indicative of follow-ups well after weaning). This indicates that prior to approximately age four, children are relatively more buffered from seasonal food shortages, after which season becomes a significant determinant of the weight trajectory. Seasonality should be considered in designing interventions for at least those children older than two years; all of the prior research in these two communities indicates that supplementation is most needed during the rainy (hungry) season. In addition to seasonality, local variations in conditions contribute to variation in children's growth patterns. In all previous work, higher proportions of children in Ossu show poor growth and there is a trend for that difference even in this more limited, younger sample. Thus, *variations in broader ecological influences across rural Timor-Leste contribute to variation in growth patterns in children* (Spencer et al. 2018b; Spencer et al. 2017).

This report provides a useful comparison between the use of large cross-sectional datasets in comparison to smaller, longitudinal subsamples. Herein, children's weight for age declines with follow-ups (which coincide with older age). Similarly, in previous cross-sectional analyses of the population from which the longitudinal sample is extracted, standardized growth measures declined with age – especially in boys (Spencer et al. 2018a). The majority of children showed both positive and negative shifts in growth trajectories (numerous changes with little variation from baseline). This suggests that poorer growth with age is not simply a cumulative deficit resulting from consistently limiting conditions. We know that growth in the first two years of life is a strong predictor of later life growth (Spencer et al. in prep). Given the importance of the first two years to later growth and the ability of children to recover when conditions allow, *interventions should be targeted as close to birth as possible to minimise the likelihood that children incur growth deficits prior to the commencement of any programme.*

All previous analyses of the longitudinal data set indicated that subdistrict and sex of the child explained some of the variation in z scores; this is not evident when outcome measures as categorized relative to stunting, underweight or wasting. We recommend that analyses that search for variates explaining variation in anthropometric scores use the z score rather than a categorization of (for example) stunted versus not stunted.

<u>Key points</u>

Measurements of children after the rainy season are more likely to catch them at lower points on their growth trajectories. Slowing of growth over the rainy season suggests that interventions provided during this period of food scarcity might be more beneficial than during the harvest (when children may recoup some of the condition lost over the rainy season). Thinking about interventions in terms of reducing the number of negative changes in growth trajectory may suggest new models of intervention.

While children's condition in the first two years influences their later growth, they remain able to change growth trajectories as conditions improve. Repeated incidences of poor conditions over time and reduced buffering of weaned children from environmental scarcity may result in poorer growth outcomes for older children than are observed in younger children.

Wasting is not a good measure of stunting concurrently, nor is it predictive of future stunting. Neither is stunting associated with or predictive of future wasting. The majority of children are below international norms in both weight and height. Thus, wasting identifies only the most extreme cases of poor growth.

<u>Bibliography</u>

Binkin, N. J., Yip, R., Fleshood, L., & Trowbridge, F. L. (1988). Birth Weight and Childhood Growth. *Pediatrics*, 82(6), 828-834.

de Onis, M., Garza, C., Victora, C. G., Onyango, A. W., Frongillo, E. A., & Martines, J. (2004). The WHO Multicentre Growth Reference Study: planning, study design, and methodology. *Food and Nutrition Bulletin*, 25(1 suppl1), S15-S26.

General Directorate of Statistics, Ministry of Health, & ICF (2018). *Timor-Leste Demographic and Health Survey 2016*. Dili, Timor-Leste and Maryland, USA.

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

Reghupathy, N., Judge, D. S., Sanders, K. A., Amaral, P. C., & Schmitt, L. H. (2012). Child size and household characteristics in rural Timor-Leste. *American Journal of Human Biology*, 24(1), 35-41, doi:10.1002/ajhb.21232.

Sanders, K. A., Judge, D. S., Pauli, N., Amaral, P. C., & Schmitt, L. H. (2014). The influence of sex, age and season on child growth in Ossu sub-district, Timor Leste, 2009-2012. In H. Loney, A. da Silva, N. Mendes, A. da Costa Ximenes, & Fernandes C. (Eds.), *Understanding Timor-Leste 2013* (Vol. 2, pp. 190-198): Swinburne Press.

Sellen, D. W. (2007). Evolution of infant and young child feeding: Implications for contemporary public health. *Annual Review of Nutrition*, 27(1), 123-148, doi:10.1146/annurev.nutr.25.050304.092557.

Spencer, P. R., Sanders, K. A., Canisio Amaral, P., & Judge, D. S. (2017). Household resources and seasonal patterns of child growth in rural Timor-Leste. *American Journal of Human Biology*, 29(1), e22916, doi:10.1002/ajhb.22916.

Spencer, P. R., Sanders, K. A., & Judge, D. S. (2018a). 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, doi:10.1002/ajpa.23350.

Spencer, P. R., Sanders, K. A., & Judge, D. S. (2018b). Rural livelihood variation and its effects on child growth in rural Timor-Leste. *Human Ecology*, 46(6), 787-799.

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

UNICEF (2013). https://www.unicef.org/progressforchildren/2007n6/index_41505.htm

World Health Organization (2006). *WHO Child Growth Standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development*. Geneva: World Health Organization.

World Health Organization NLIS (2010). https://www.who.int/nutrition/nlis_interpretation_guide.pdf