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Growth faltering and recovery in children aged 1–8 years in four low- and middle-income countries: Young Lives

Abstract

Objective: We characterized post-infancy child growth patterns and determined the incidence of becoming stunted and of recovery from stunting.

Design: Data came from Young Lives, a longitudinal study of childhood poverty in four low- and middle-income countries (LMICs).

Setting: We analyzed length/height measurements for children at ages 1, 5, and 8y.

Subjects: 7,171 children in Ethiopia, India, Peru and Vietnam.

Results: Mean height-for-age z-score (HAZ) at age 1y ranged from -1·51 (Ethiopia) to -1·08 (Vietnam). From age 1 to 5y, mean HAZ increased 0·27 SD in Ethiopia (p<0·001) and decreased among the other cohorts (range: -0·19 (Peru) to -0·32 (India)) (all p<0·001). From 5 to 8y, mean HAZ increased in all cohorts (range: 0·19 (India) to 0·38 (Peru)) (all p<0·001). Prevalence of stunting (HAZ<-2·0) at 1y ranged from 21% (Vietnam) to 46% (Ethiopia). From age 1 to 5y, stunting prevalence decreased 15·1 percentage points (PP) in Ethiopia (p<0·001) and increased in the other cohorts (range: 3·0 PP (Vietnam) to 5·3 PP (India)) (all p≤0·001). From 5 to 8y, stunting prevalence decreased in all cohorts (range: 5·0 PP (Vietnam) to 12·7 PP (Peru)) (all p<0·001). The incidence of becoming stunted between ages 1 to 5y ranged from 11% (Vietnam) to 22% (India); between ages 5 to 8y, it ranged from 3% (Peru) to 6% (India and Ethiopia). The incidence of recovery from stunting between ages 1 and 5y ranged from 27% (Vietnam) to 53% (Ethiopia); between ages 5 and 8y, it ranged from 30% (India) to 47% (Ethiopia).

Conclusions: We found substantial recovery from early stunting among children in four LMICs.

Introduction

Characterizing child growth patterns, including the incidence of becoming stunted and of recovery from stunting, in low- and middle-income countries (LMICs) is important for understanding the determinants and consequences of childhood growth trajectories and for developing effective interventions and policies. Cross-sectional data from the Demographic and Health Surveys (DHS) show that on average children in LMICs experience rapid growth faltering during the first two years of life, with height-for-age z scores (HAZ), the preferred indicator of long-run nutritional status, declining dramatically over the first 24 months of life and increasing only slightly after then [(1)]. These and similar findings have been used to suggest that recovery after two years of age is unlikely and therefore the "window of opportunity" for preventing undernutrition ends at two years.

Nutritional interventions are increasingly targeted toward children under two years, as it has been suggested that, similar to linear growth retardation, the cognitive and developmental deficiencies resulting from poor growth may also be largely irreversible after about two years of age [(2-8)]. However, some evidence challenges these findings [(9-17)] and suggests that there is significant opportunity for both catch-up growth, as well as the associated cognitive and schooling improvements, following post-infancy growth stunting. Such evidence may support a complementary approach focused on identifying and targeting children post-infancy who are stunted or at risk for growth faltering, for further nutritional or health interventions. There are few published longitudinal studies of child growth and its consequences for health and development (Adair et al., 1999 [(18)] is an exception), limiting the conclusions that can be drawn about child growth trajectories in LMICs.

Our study addresses this gap in the literature by presenting longitudinal child growth data from population-based cohorts in four LMICs. We analyzed data on growth patterns of children post-infancy (≥ 12 mo), in order to describe growth patterns and determine the incidence of becoming stunted, and of recovery from stunting.

Subjects and Methods

Young Lives Study

Young Lives is a longitudinal study of the causes and consequences of childhood poverty in Peru, Vietnam, India, and Ethiopia [19]. Within each country, the study follows a cohort of ~2000 children (there is also an older cohort of about half this size). The Young Lives Project used a multi-stage sampling strategy, whereby the first stage consisted of the selection of 20 sentinel sites (clusters) per country using a sampling methodology referred to as the Sentinel Site Surveillance system. In each country, the sentinel sites were selected in a semi-purposive manner based on socioeconomic, demographic, geographic, and policy variables that were relevant to the project. In Peru, Vietnam and Ethiopia, a nationwide sampling frame was used, whereas in India the sentinel sites were selected within the state of Andhra Pradesh. The sampling frame allowed for oversampling for poor areas and a mixture of urban and rural areas. In the second stage, within each sentinel site, households with a child in the target age range were enumerated and approximately 100 index children were selected according to comparable, but country-specific, protocols that were analogous to statistical random sampling. Refusal rates among selected households were <2% in all four countries, and in the case of refusal, replacement sampling was used [19]. These sampling methods resulted in a sample for each country that reflected the ethnic, geographic, and religious diversity of the population, but that was not chosen to be directly nationally representative. Further details on the sampling strategy used within each country can be found in the Preliminary National Reports accessible at http:/www.younglives.org.uk/. Data collection took place in 2002 (round 1, age 6-18 mo), in 2006-2007 (round 2, age 4·5 to 5 y), and in 2009-2010 (round 3, age 7 to 8 y). Supine length (round 1) and standing height (rounds 2 and 3) were measured with length/height boards using standardized WHO methodology [20] and measurements precise to 1mm. The length and height measurements were converted to z scores (HAZ) using WHO standards [21-23].

Data Cleaning and Analysis

Length measurements were available at recruitment for 1,946 children in Ethiopia, 1,992 children in India, 2,040 children in Peru, and 1,990 children in Vietnam. Data were excluded from analysis if the child was not in the target age range (6-17·9 months) at recruitment (0 children in Ethiopia, 39 in India, 27 in Peru, and 69 in Vietnam); was not measured at all three rounds (115 children in Ethiopia, 87 in India, 146 in Peru, and 72 in Vietnam); or had HAZ values that were implausible, defined as |HAZ| > 5 at any one round or an absolute value of change in HAZ between rounds > 4 (121 children in Ethiopia, 70 in India, 32 in Peru, and 19 in Vietnam). After these exclusions, data were available for 7,171 children (1,710 in Ethiopia, 1,796 in India, 1,835 in Peru, and 1,830 in Vietnam), representing 90% of the original sample. Children who were younger at recruitment tended to have higher HAZ scores and children who were older at recruitment tended to have lower HAZ scores (**Figure 1**). Failing to account for the variability in age at recruitment would distort an assessment of the incidence of becoming stunted and of recovery between rounds 1 and 2, because children who were older than 12 months at round 1 would be coded as having greater recovery than they otherwise would have had they been recruited at 12 months, while children who were younger than 12 months at round 1 would be coded as having greater incidence of stunting than they otherwise would have, assuming that over short periods of time children track along the growth trajectory that is typical of the community in which they live. Therefore, we adjusted round 1 HAZ by adding the difference between the child's observed HAZ and the site-specific mean HAZ for all children within +/- 1 month of the child's age to the site-specific mean HAZ for children ages 11-13 months. Overall, there was little difference by month of age in mean HAZ in rounds 2 and 3, and therefore we did not conduct a similar adjustment for these rounds.

Characterizing Growth

We compared the mean values for HAZ at each round and the mean within-child change in HAZ between rounds. We computed the prevalence of stunting (HAZ < -2·0) in each round as well as the incidence of becoming stunted (the proportion of children who were not stunted in an earlier round but were stunted at a later round) and of recovery (the proportion of children who were stunted in an earlier round but were not stunted at a later round). Tests of statistical significance were carried out using linear regression analyses that accounted for both the paired nature of the data, as well as the clustering within the data due to sampling procedures; all p-values are presented as two-sided. We also determined the extent to which HAZ measurements at earlier ages predict HAZ at later ages by regressing HAZ at round 2 on the HAZ score at round 1, and by regressing HAZ at round 3 on HAZ at rounds 1 and 2. We used the Intercooled STATA 10.0 (StataCorp, College Station, Texas) statistical program for all data analyses.

Results

The average age at recruitment was 12·2 months, with some variation across cohorts (**Table 1**). At round 1, the Ethiopian cohort had the lowest mean HAZ (-1·51), and the Vietnamese cohort had the highest (-1·08) (**Table 2**). From round 1 to round 2, mean HAZ increased among Ethiopian children (0·27; p<0·001) and decreased among the other cohorts (range -0·19 to -0·32; all p<0·001). From round 2 to round 3, mean HAZ increased in all four cohorts (range 0·19 to 0·38; all p<0·001). At round 1, the Ethiopian cohort had the highest prevalence of stunting (46%), and the Vietnamese cohort had the lowest (21%). From round 1 to round 2, the Ethiopian cohort experienced a 15·1 percentage points [PP] reduction in the prevalence of stunting (p<0·001), while the prevalence of stunting increased (range 3·0 to 5·3 PP; all p≤0·001) in the other three cohorts. From round 2 to round 3, the prevalence of stunting decreased (range 5·0 to 12·7 PP; all p<0·001) in all four cohorts. Taking the whole study period, from round 1 to round 3, there was a significant decrease in the prevalence of stunting in Ethiopia (25·4 PP; p<0·001), Peru (8·3 PP; p<0·001), and Vietnam (2·0 PP; p=0·04); however, the decrease of 0·8 PP in India was not significant (p=0.45).

From round 1 to round 2, the majority of children had a change in HAZ ≥ 0·50 (**Figure 2**), whereas from round 2 to round 3, the majority of children experienced a change in HAZ ≤ 0·49.

The incidence of becoming stunted from round 1 to round 2 ranged from 11% (Vietnam) to 22% (India) (**Table 3**), and from round 2 to round 3 ranged from 3% (Peru) to 6% (India and Ethiopia). The incidence of recovery ranged from 27% (Vietnam) to 53% (Ethiopia) between rounds 1 and 2, and from 30% (India) to 47% (Ethiopia) between rounds 2 and 3. From round 1 to round 3, the incidence of becoming stunted ranged from 8% (Peru) to 18% (India), and the incidence of recovery ranged from 45% (Vietnam) to 67% (Ethiopia).

When HAZ at round 2 was regressed on HAZ at round 1, the r-squared was 0·26 in Ethiopia, 0·33 in India, 0·47 in Peru, and 0·60 in Vietnam; therefore, between 26% to 60% of the variability in HAZ at round 2 was predicted by HAZ at round 1. When HAZ at round 3 was regressed on HAZ at rounds 1 and 2, the r-squared was 0·53 in Ethiopia, 0·65 in India, 0·71 in Peru, and 0·73 in Vietnam; therefore, between 53% to 73% of the variability in HAZ at round 3 was predicted by HAZ at rounds 1 and 2.

Discussion

We analyzed child growth patterns using HAZ scores at ages 1, 5, and 8 years for 7,171 children in four LMICs participating in the Young Lives Study. Cross-sectional data from round 1 demonstrated decreasing mean HAZ scores between ages 6-18 mo. Three of the four countries continued to experience declining HAZ scores between age 1 and age 5. Mean HAZ increased in all four countries between age 5 and age 8. While stunting status at round 1 was predictive of stunting at rounds 2 and 3, there was substantial recovery from early stunting, with recovery rates ranging from 27% to 53% between rounds 1 and 2, and from 30% to 47% between rounds 2 and 3. Intra-child height measurements over time are highly correlated, reflecting a combination of genetic predisposition and environmental influences that affect linear growth. However, a substantial proportion of the variability in HAZ at age 5 (40-74%) and HAZ at age 8 (27-47%) was not predicted by HAZ measurements at earlier time points.

The data we used were collected through a large, multi-country longitudinal study, using standardized anthropometric procedures and rigorously trained field workers, and provided four diverse country contexts with which to study child growth patterns. However, several limitations of the data merit discussion. The Young Lives study began collecting data when the children were 6-17·9 months, so length at birth is not consistently available. Round 1 data were collected during an age period in which growth faltering occurs in many LMIC settings [1], and indeed our data show this age-related decrease in length-for-age. We addressed this challenge by internally adjusting our data to age 12 mo. Length was not measured at age 2 y, the age at which HAZ generally reaches its nadir [1]. However, data from the INCAP nutrition supplementation study showed that HAZ scores at ages 6, 12, and 18 months are strongly correlated with HAZ at age 24 months (r=0·74, 0·83, 0·91, respectively; all p<0·001), suggesting that HAZ between ages 6-18 months can serve as a reasonable proxy for HAZ at age 24 months [24]. Additionally, having only three length/height measurements (at ages 1, 5, and 8) limits our ability to characterize post-infancy child growth patterns.

In the present analysis, the calculation of z-scores used growth standards from two distinct populations. The child growth standards used to calculate z-scores for the Young Lives cohorts at one year of age come from the longitudinal World Health Organization Multicentre Growth Study, a population of exclusively or predominantly breastfed children. The data for these growth standards end at five years of age, so the WHO developed reference charts for children older than five years based on cross-sectional data from the 1977 U.S. National Center for Health Statistics study of child growth, where feeding type was not controlled [(22)]. We used these WHO reference charts for older children in the calculation of z-scores at five and eight years of age. This can limit the comparability of the z-scores at the three time points, and suggests that the data should be interpreted carefully.

The results of this analysis are based on data from four diverse country contexts, and we aimed to present and interpret country-specific findings, while also discussing growth patterns that were common across the sites. We did not, however, attempt to explain sources of variation across sites in the magnitude of growth failure and the incidence of stunting and recovery from stunting, as such an analysis would require far more sites than the four in Young Lives, and the models would quickly become saturated.

This analysis has several strengths. When compared to other longitudinal studies that have collected child growth data, such as those participating in the COHORTS collaboration [(25)], the Young Lives study provides unique data with which to characterize child growth patterns. The Young Lives study provides more recent data on children born at about the same time the Millennium Development Goals (MDGs) were established. The data were collected longitudinally within four diverse population-based cohorts using a study-wide standardization and training process. With its emphasis on LMICs, the Young Lives study is well-positioned to document the incidence and timing of stunting and recovery among post-infancy children in MDG-focused countries characterized by poor childhood nutrition and growth.

Our data demonstrate that while child growth trajectories throughout the preschool and early school-age years are predicted in part by size at age 1, there is significant variation in growth after age 1 y. This includes catch-up growth in some children and faltering in others. These results suggest that while prevention of early-life stunting must continue to be a top priority, program planners and implementers should consider identifying and targeting for further nutritional interventions children who nevertheless become stunted during infancy, as well as children at risk for later growth faltering. An important area for future research is identifying the factors that contribute to these later variations in growth.

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Tables

Table 1. Baseline Characteristics of Children in the Young Lives Cohorts[1]

Characteristics	**Ethiopia**	**India**	**Peru**	**Vietnam**
Number of children	1,710	1,796	1,835	1,830
Age at recruitment (mo) (mean (SD))	12·2 (3·6)	12·2 (3·4)	12·0 (3·5)	12·3 (3·1)
Male (%)	53·2	53·4	50·1	51·2

1 Based on children in the present analysis.

Table 2. HAZ measures at 1, 5 and 8 y and changes in HAZ between these ages, among children in the Young Lives study, by country

	Ethiopia (n = 1,710) Mean (SD)	Range	**India** (n = 1,796) Mean (SD)	Range	**Peru** (n = 1,835) Mean (SD)	Range	**Vietnam** (n = 1,830) Mean (SD)	Range
HAZ Round 1 (age 1 y)	-1·51 (1·58)	(-4·98, 4·59)	-1·30 (1·35)	(-4·87, 4·61)	-1·29 (1·22)	(-4·95, 3·23)	-1·08 (1·15)	(-4·94, 3·81)
HAZ Round 2 (age 5 y)	-1·46 (1·04)	(-4·84, 2·00)	-1·63 (0·95)	(-4·71, 3·13)	-1·51 (1·08)	(-4·61, 2·05)	-1·33 (1·01)	(-4·65, 2·87)
HAZ Round 3 (age 8 y)	-1·21 (1·00)	(-4·87, 3·56)	-1·43 (0·99)	(-4·87, 2·21)	-1·13 (1·02)	(-4·29, 2·17)	-1·09 (1·03)	(-4·50, 2·88)
HAZ change Rounds 1 to 2	0·27 (1·35)	(-3·84, 3·92)	-0·32 (1·11)	(-3·99, 3·89)	-0·19 (0·90)	(-3·78, 3·51)	-0·21 (0·72)	(-3·58, 3·52)
HAZ change Rounds 2 to 3	0·25 (0·78)	(-2·56, 3·99)	0·19 (0·62)	(-3·23, 3·93)	0·38 (0·62)	(-2·31, 3·62)	0·24 (0·55)	(-3·42, 3·40)
Stunting (HAZ < -2.0) (%)								
Round 1 (age 1 y)	45·5	-	29·3	-	27·9	-	21·2	-
Round 2 (age 5 y)	30·4	-	34·6	-	32·3	-	24·2	-
Round 3 (age 8 y)	20·1	-	28·5	-	19·6	-	19·2	-

Note: Mean (SD) unless otherwise noted.

Table 3. Incidence of stunting[1] and of recovery[2] from stunting among children in the Young Lives study, by country							
Country	**Round**	**HAZ Status**	**Status at Round 1 %**	**Status at Round 2**		**Status at Round 3**	
				HAZ < -2.0 %	HAZ ≥ -2.0 %	HAZ < -2.0 %	HAZ ≥ -2.0 %
Ethiopia n=1,710	1	HAZ < -2·0	45·5	47·4	52·6	32·9	67·1
		HAZ ≥ -2·0	54·5	16·1	83·9	9·3	90·7
India n=1,796	1	HAZ < -2·0	29·3	65·3	34·7	54·3	45·7
		HAZ ≥ -2·0	70·7	21·9	78·1	17·7	82·3
Peru n=1,835	1	HAZ < -2·0	27·9	69·7	30·3	49·2	50·8
		HAZ ≥ -2·0	72·1	17·8	82·2	8·1	91·9
Vietnam n=1,830	1	HAZ < -2·0	21·2	72·9	27·1	54·8	45·2
		HAZ ≥ -2·0	78·8	11·2	88·8	9·6	90·4
			Status at Round 2 %				
Ethiopia n=1,710	2	HAZ < -2·0	30·4			52·6	47·4
		HAZ ≥ -2·0	69·6			5·9	94·1
India n=1,796	2	HAZ < -2·0	34·6			70·3	29·7
		HAZ ≥ -2·0	65·4			6·3	93·7
Peru n=1,835	2	HAZ < -2·0	32·3			53·9	46·1
		HAZ ≥ -2·0	67·7			3·2	96·8
Vietnam n=1,830	2	HAZ < -2·0	24·2			65·2	34·8
		HAZ ≥ -2·0	75·8			4·5	95·5

1 Incidence of stunting is the proportion of children who were not stunted at an earlier survey round but were stunted at a later survey round (stunting is defined as HAZ <-2.0)
2 Incidence of recovery is the proportion of children who were stunted at an earlier survey round but were not stunted at a later survey round