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Birth Size, Stunting and Recovery from Stunting in Andhra Pradesh, India: Evidence from the Young Lives Study

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Abstract *Objectives* Few Indian studies have examined the relationship between birth size and stunting in children. Studies on recovery from stunting in India are even fewer. This study, thus, investigates the relationship between birth size and stunting in Andhra Pradesh, India. This study further examines the factors associated with recovery from stunting using a longitudinal data. *Methods* We used data from the three waves of Young Lives Study (YLS) conducted in Andhra Pradesh in the years 2002, 2006–2007, and 2009 respectively. We used data from 1965 children in wave 1 to examine the association between birth size and stunting. For examining the factors associated with recovery from stunting between 1 and 5 years of age, and between 5 and 8 years, we use data from 582 and 670 children who were stunted at age 1 and age 5 respectively. We use multivariable logistic regression models to fulfil the objectives of the paper. *Results* The children who were of average- or large- size at birth were significantly less likely to be stunted than children who were of small size at birth (OR 0.61 and 0.47 respectively). Children of average/tall mothers were 0.41 times less likely to be stunted than children of shorter mothers. Severely stunted children were less likely than other stunted children to recover from stunting between 1 and 5 years of age, and between 5 and 8 years. Mother's height was statistically associated with recovery. Change in wealth status of the household was statistically associated with recovery between 1 and 5 years of age. In comparison, child immunization was associated with recovery between 5 and 8 years. *Conclusions for Practice* This study contributes to the understanding of the impact of birth size on childhood stunting, and to the extent of recovery from stunting in India. Further follow-up is necessary to demonstrate the impact during adolescence and adulthood.

Keywords Birth size · Stunting · Recovery from stunting · Young Lives Study · India

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Significance of the study

This study is perhaps the first study in India that examines the relationship between birth size and stunting in early childhood. Furthermore, this study, for the first time, highlights the factors associated with recovery from early childhood stunting. A novelty of the study is that it uses a longitudinal dataset to investigate the factors associated with recovery. The study is based on three waves of data collected in years 2002, 2006–2007, and 2009.

Introduction

Malnutrition in young children is one of the important public health concerns in India. Recent data from the Indian National Family Health Survey (NFHS) 2005–2006 suggests that 45 % of children under age 3 years are stunted. Likewise, 40 % of the children under age 3 are underweight (IIPS and ORC Macro 2007). Trends in stunting and underweight reveal only marginal declines over the last two NFHS rounds (IIPS and ORC Macro

2007). Notably, India accounts for 33 % of the total burden of stunting in the world (UNICEF 2013). Such a high prevalence of stunting is a matter of serious concern because stunted children are at a higher risk of developing diarrheal disease, acute respiratory infections (ARI) and other infectious diseases (Etiler et al. 2002; Sarkar et al. 2014). Another concern related to stunting is that it passes from one generation to another (Ramakrishnan et al. 1999; UNICEF 1998).

One of the important factors affecting stunting in young children is birth weight/size (Christian et al. 2013; Espo et al. 2002; Kroupina et al. 2014; Pedraza and de Menezes 2014; Rehman et al. 2009). Babies who are small at birth or have low birth weight (<2.5 kg) tend to develop into stunted children (Hack et al. 2003; Saigal et al. 2006; Sridhar et al. 2002). A literature search yielded only one study from India that has examined the relationship between birth weight/size and stunting in young children (Rehman et al. 2009). A birth weight of less than 2.5 kilograms was statistically associated with stunting at 3 years of age in children (Rehman et al. 2009). The study by Rehman et al. (2009) was based on three south Indian slums (measured area of 2.2 sq. km. with a population density of 17,000 per sq. km.), and lacked representativeness. Hence, we aim to examine the relationship between birth weight/size and stunting in young children in India using a larger and representative data.

Another subject worth exploring is the determinants of recovery from early childhood stunting. Some studies have suggested that in the context of developing countries, likelihood of recovery is essentially impossible (Checkley et al. 2003; de Onis 2003; Martorell et al. 1994; Mendez and Adair 1999). In contrast, a few studies have shown that partial recovery from early childhood stunting is possible in later childhood and adolescence (Adair 1999; Bowie et al. 1980; Golden 1994; Kulin et al. 1982; Satyanarayana et al. 1989; Tanner 1981). Earlier studies that have examined the determinants of recovery from stunting have shown that severity of stunting, timing of stunting, birth weight/birth size, number of siblings, birth order, sex of child, breastfeeding practices, exposure to better environments, good nutrition, consumption of vitamin A, mother's height, mother's education, and place of residence are statistically associated with recovery from stunting (Adair 1999; Shrimpton et al. 2001; Tanner 1981; Vella et al. 1994). Notably, there are only two studies from India that have examined the factors associated with period of child growth up to age 8 years (Lundeen et al. 2014; Schott et al. 2013).

Given the limitations of the previous studies and the inconclusive evidence regarding the factors associated with recovery from stunting in India, we use a longitudinal data to examine the impact of birth size on childhood stunting, and the factors associated with recovery from early childhood stunting in Andhra Pradesh province of India.

Methods and Materials

Data

We used data from the first, second and third waves of the Young Lives Study (YLS), which was conducted in Andhra Pradesh India during 2002, 2006–2007 and 2009. Young Lives is an international longitudinal study investigating the changing nature of childhood poverty. Twelve thousand children are being followed in four countries: Ethiopia, Peru, Vietnam and India (Andhra Pradesh). Each country has two cohorts: younger cohort and older cohort. The younger cohort consists of 2000 children born in 2001–2002 and the older cohort consists of 1000 children born in 1994–1995 to be followed over a period of 15 years (Barnett et al. 2012; Wilson et al. 2006). The YLS is conducted every 3/4 years to collect data on a range of indicators related to the growth and development of children. YLS collects information on child welfare outcomes including nutritional status, growth, physical health, cognitive development, social and emotional well-being and educational development (Barnett et al. 2012; Dercon and Singh 2013; Wilson et al. 2006).

A multistage sampling design was adopted in YLS. In the first stage, two districts were selected from each of the three geographic regions (Coastal, Rayalseema and Telangana) of Andhra Pradesh. A poor and a non poor district were selected from each geographical region based on economic, human and infrastructure development indicators in such a way that there was uniform distribution of sample districts across the three geographical regions. In the second stage, 19 (15 from rural areas and four from urban areas) sentinel sites (administrative blocks or 'mandals') were selected from the six selected districts. In addition, one sentinel site was selected from the urban slums of the city of Hyderabad. In the third stage, villages were selected from rural sentinel sites and wards were selected from the urban sites. In order to select villages in rural areas, each sentinel site was divided into four contiguous geographic area and one village was randomly selected from each area in such a way that the four villages selected from each sentinel sites had threshold populations to give 100 households with a 1 year old child (born in 2001–2002) and 50 households with an 8 years old child (born in 1994–1995). In urban areas wards were defined as community. Before data collection began in the selected communities, a door to door listing was carried out in order to identify the eligible children. Overall, 2011 households (with 2011 children) in the younger cohort and 1008 households (with 1008 children) in the older cohort were included in the first wave of YLS, which was conducted in 2002 [for details of YLS sampling design, see Barnett et al. (2012), Morrow et al. (2014) and Wilson et al. (2006)].

The second wave took place between late 2006 and early 2007. Of the 2011 children recruited in the first wave, 32 children died, 7 refused to continue with the study, and 22 children were untraceable. Hence, the second wave included only 1950 children. Third wave took place in 2009 and included 1930 children (of 1950 children in wave two, 4 children died, 5 refused to continue with the study, and 11 were untraceable) in the younger cohort. The attrition rate between wave one and wave two was about 3 % and between wave two and wave three was about 1 % (Barnett et al. 2012).

The interviewers were thoroughly trained in collecting and compiling anthropometric data. Special training on conducting anthropometric measurements, similar to that provided in National Family Health Survey (Indian DHS), was provided to the field investigators. Strict and well-prepared protocols were in place to supervise the field work and to ensure quality control during the field work. Data were checked for any inconsistencies. Additional methodologic details are available elsewhere (Galab et al. 2003).

Dependent Variables

The dependent variables of interest are stunting and recovery from stunting. Children with height-for-age z-score (HAZ) below minus two standard deviations ($HAZ < -2SD$) from the median of the reference population are considered short for their age or stunted. Such children are also considered chronically malnourished (IIPS and ORC Macro 2007). Notably, there is no standard definition of recovery. In general, recovery refers to the improvement in height-for-age z-score after being stunted during early childhood. For the present analysis, recovery between 1 and 5 years of age is defined as $HAZ < -2SD$ at age 1, but $HAZ \geq -2SD$ at age 5. Recovery between 5 and 8 years of age was defined in a similar way. Height-for-age z-score in each wave was based on the World Health Organization (WHO) standard for children under age 5 years and the WHO 2007 standard for school-going children (de Onis et al. 2007). The international standard allows for the comparison of height-for-age z-score over age groups and sex (Wang and Chen 2012; WHO 2015).

Height of children was measured in centimetres (cm) to the nearest agreed 0.1 cm, with fixed head and movable foot piece. The fieldworkers were trained extensively and standardized in anthropometric measurement according to the World Health Organization (WHO) protocols (Crookston et al. 2011). Height of children below age 2 years (in wave-1) was measured using length board. Two persons were engaged for measuring the child's height; one held the child head and other measured the length. Height of children in waves 2 and 3 were measured using a height stick. Two independent readings were taken before finalising the height in each wave of YLS. If the measurement was not same, measures were repeated and only those measures which were repeatable were accepted.

Independent Variables

The independent variables included in the analysis of birth size and stunting in early childhood are birth size (small; average; large), premature birth (no; yes), age of child (in months), sex of the child (male; female), ever breastfed (no; yes), number of siblings (0; 1; ≥2), mother's years of schooling (0–4 years; ≥5 years), mother's working status (household work; others), mother's height (short <145 cm; average/tall ≥145 cm), mother's age at birth of the child (<18 years; ≥18 years), mother received antenatal check-up (<4 ANC; ≥4 ANC), mother consumed iron folic acid supplementation(<3 months; ≥3 months), mother received tetanus injection (<2 TT; ≥2 TT), years of schooling of the household head (0–4 years; ≥5 years), caste (scheduled tribes; scheduled castes; other backward classes; others), wealth index (poor; middle; rich), toilet facility (improved; non-improved), drinking water (safe; unsafe) and place of residence (rural; urban).

Some additional independent variables were identified and included in the analysis of factors affecting recovery from early childhood stunting. These variables included height-for-age z-score of children in the previous round ($HAZ < -3SD$; $-3SD \leq HAZ < -2SD$), immunization (no/partial; full), consumption of milk (no; yes), consumption of fruit (no; yes), consumption of egg (no; yes), consumption of fish (no; yes), consumption of meat (no; yes), change in energy intake (low, no change in energy intake; low, increase in energy intake; high, decrease in energy intake; high no change in energy intake), food shortage (no; yes), change in household's wealth status (always below the poverty point; household moved from below poverty point to on or above the poverty point; household moved from on or above poverty point to below poverty point; always on or above the poverty point).

The survey collected data on respondent's (mother/caregiver) perception about size of the baby at birth. YLS asked the respondent when child was born he/she was very small, small, average, large or very large? Very small or small size at birth was coded as 'small', and large or very large size at birth was coded as 'large'.

The wealth index was calculated using wealth scores, which are already computed and given in the YLS dataset. The wealth scores were generated through a principle component analysis conducted on a set of variables based on household assets (including radio, refrigerator, bicycle, television, motorbike/scooter, car, pump, sewing machine, mobile phone, landline telephone, fan, almirah, clock, table, chair, sofa, bedsheet and animals), household quality (including wall, roof and floor) and services (including electricity, drinking water, toilet facility). The lowest 33.3 % households were coded as poor, the next 33.3 % as middle and the remaining 33.3 % as rich.

To assess the effect of the change in wealth status on recovery, we defined poverty point using wealth scores in each of three waves. Poverty point refers to the mean of wealth scores between 45th and 55th percentiles (Xu 2005). Households below the poverty point were categorized as 'households below the poverty point' and the rest were categorized as 'households on or above the poverty point'. Therefore, the categories of the variable 'change in household's wealth status' between two consecutive waves were always below the poverty point, household moved from below poverty point to on or above the poverty point, household moved from on or above poverty point to below poverty point, always on or above the poverty point.

Information on energy intake was gathered from 24-hour dietary recalls during waves 2 and 3. The YLS asked mothers five questions related to dietary intake:

1. During previous 24-hour did child consume milk? (No/Yes)
2. During previous 24-hour did child consume fruit? (No/Yes)
3. During previous 24-hour did child consume egg? (No/Yes)
4. During previous 24-hour did child consume fish? (No/Yes)
5. During previous 24-hour did child consume meat? (No/Yes)

If the child consumed any two of the aforementioned food items 'energy intake' was coded as 'high energy intake'. Otherwise, it was coded as 'low energy intake'. Therefore using information on energy intake during waves two and three we were able to assess the effect of change in energy intake (low, no change in energy intake; low, increase in energy intake; high, decrease in energy intake; high, no change in energy intake) on recovery between waves 2 and 3. However, for recovery between waves one and two, direct information on consumption of milk, fruit, egg, fish, and meat were used as energy intake. This was done because the first wave of YLS did not collect information on the consumption of aforementioned items. The aforementioned information was not collected in wave one for the simple reason that the age of children was between 5 and 21 months in wave one.

Information on food shortage was gathered during waves 2 and 3. The YLS asked: in past 12 months has the household had any food shortage or did you ever worry that your household would run out of food before you get money to buy or could acquire more? (No; Yes)

In the second wave of YLS, the survey asked mothers whether the child had received a vaccination against tuberculosis (BCG); diphtheria, whooping cough (pertussis) and tetanus (DPT); poliomyelitis (Polio) and measles. Children who received all the aforementioned vaccinations were coded as 'fully immunized'. The remaining children were coded as 'no/partially immunized'.

YLS also collected information on the main source of drinking water. Children were classified into two categories according to whether the households they lived in used safe or unsafe water supply for drinking. Households having piped water into dwelling/yard/plot or using public tap/standpipe or using a tube well/borehole or protected dug well were considered as using safe drinking water. Other households were categorized as using unsafe drinking water. Information on the type of toilet facility used by household was also gathered in each of three waves of YLS. Improved toilet facilities include flush toilet/pit latrine connected to a septic tank. Non-improved toilet facilities include public/shared facility, simple latrine, toilet in a health post or forest/field/open place (UNICEF and WHO 2012).

Analysis

We used data from only the first wave of YLS for examining the impact of birth size on early childhood stunting. Of the 2011 children recruited in the original YLS cohort, we included 1965 children that had complete information on birth size, height-for-age z-score and other independent variables.

For examining the factors associated with recovery from early childhood stunting between 1 and 5 years of age we used data from 582 children who were stunted at age 1. Likewise, for examining the factors associated with recovery from stunting between 5 and 8 years of age we used data from 670 children who were stunted at age 5.

We used multivariable logistic regression to analyse the impact of birth size on childhood stunting. Multivariable logistic regression was also used to examine the factors associated with recovery from stunting. Stunting is a binary indicator variable of childhood nutritional status, hence '0' was assigned if HAZ ≥ -2SD and '1' otherwise. Furthermore, for recovery '0' was assigned if the child's HAZ was less than -2SD between two consecutive waves (i.e., from wave one to wave two or wave two to wave three) and '1' otherwise. All the variables were tested for multicollinearity before being included in the regression models. All the statistical computations were done in STATA 12.0.

Ethical Approval

Our study is based on a secondary dataset with no identifiable information on the survey participants. This dataset is available in the public domain for research use and hence no approval was required from any institutional review board. The data can be downloaded from the website of the United Kingdom Data Archives University of Essex after taking permission. The data for the current study was downloaded from the afore-mentioned website after taking permission (I.D. No. 70895).

Results

Table 1 presents the prevalence of stunting in 1965 young children originally included in YLS according to their background characteristics. About 31 % of the children were stunted. Prevalence of stunting varied considerably by birth size. The prevalence of stunting in children with small-, average- and large- birth size was 42, 30, and 25 % respectively. The prevalence of stunting was higher in children who were born premature compared with mature babies, who were male compared with female, who were having more siblings compared with those having less siblings, whose mothers were shorter compared with those whose mothers were taller, and whose mothers had less schooling compared to those whose mothers had more schooling. Prevalence of stunting in children also varied by the socio-economic status of the households and the urban–rural residence. Prevalence of stunting was higher in children from households using unsafe water for drinking compared with children from households using safe water. Likewise, prevalence of stunting was higher in children from households using non-improved toilet facility compared with children from households using improved toilet facility.

Results of the multivariable logistic regression model are shown in Table 2. Birth size was statistically associated with early childhood stunting. The average- or large- size children were 0.61 (95 % CI 0.48–0.79) times and 0.47 (95 % CI 0.36–0.62) times as likely as small size children to be stunted respectively. Premature births had a higher chance of being stunted compared with mature births (OR 1.45; 95 %CI 1.02–2.03). Female children were significantly less likely than male children to be stunted (OR 0.69; 95 % CI 0.56–0.85). Stunting was also statistically associated with mother's height and mother's age at birth of the index child. For example, children of average/tall mothers were 0.41 (95 % CI 0.30–0.55) times as likely as children of short mothers to be stunted. Children of mothers aged 18 years or older at the birth of the index

Table 1 Prevalence of stunting (HAZ < −2SD) by selected background characteristics among 1965 young children originally included in YLS

Variables	HAZ < −2SD	Chi^2 (p val.)	Number
Birth size			
Small	41.9	34.8 (0.00)	484
Average	29.7		883
Large	25.3		598
Premature birth			
No	30.7	4.4 (0.04)	1787
Yes	37.6		178
Sex of child			
Male	34.4	8.4 (0.00)	1053
Female	27.9		912
Child ever breastfed			
Yes	31.5	1.2 (0.278)	1912
No	24.5		53
Number of siblings			
0	30.5	9.3 (0.00)	1091
1	28.0		539
≥2	39.4		335
Mother's years of schooling			
0–4 years	36.0	31.6 (0.00)	1216
≥5 years	23.8		749
Mother's working status			
Household work	27.2	24.8 (0.00)	982
Others	36.5		983
Mother's height			
Short <145 cm	52.3	49.1 (0.00)	216
Average/tall ≥145 cm	28.8		1749
Mother's age at birth of child			
<18 years	48.1	22.6 (0.00)	160
≥18 years	29.9		1805
Mother received antenatal check-up			
<4 ANC	35.1	7.5 (0.01)	752
≥4 ANC	29.0		1213
Mother consumed iron folic acid supplementation			
<3 months	35.0	2.7 (0.10)	449
≥3 months	30.3		1516
Mother received tetanus injection			
<2 TT	34.7	1.1 (0.30)	277
≥2 TT	30.8		1688
Years of schooling of the household head			
0–4 years	36.0	28.1 (0.00)	1185
≥5 years	24.2		780
Caste			
Scheduled tribes	45.4	51.8 (0.00)	284
Scheduled castes	36.7		362
Other backward classes	30.3		905
Others	19.3		414

Table 1 continued

Variables	HAZ < −2SD	Chi^2 (p val.)	Number
Wealth index			
Poor	41.9	58.3 (0.00)	655
Middle	30.7		662
Rich	21.3		648
Toilet facility			
Improved	17.6	36.5 (0.00)	364
Non-improved	34.5		1601
Drinking water			
Safe	30.9	3.5 (0.06)	1658
Unsafe	35.5		307
Place of residence			
Rural	34.8	28.2 (0.00)	1467
Urban	21.3		498
Total	31.4 %		1965

child were 0.52 (95 % CI 0.36–0.74) times as likely as children of mothers aged 17 years or less to be stunted.

The wealth index was also statistically associated with stunting. Children from middle- and rich-households were 0.71 (95 % CI 0.55–0.92) and 0.67 (95 % CI 0.46–0.98) times as likely as children from poor households to be stunted. Another key finding relates to the association between the type of toilet facility and stunting. Children from households using non-improved toilet facility were 1.53 (95 % CI 1.02–2.29) times as likely as children from households using improved toilet facility to be stunted.

Notably, 582 children were stunted in wave one. Table 3 presents the percentage of children who recovered from stunting between 1 and 5 years of age. Of the 582 children who were stunted at age 1, 35 % children recovered between 1 and 5 years. Recovery was less pronounced in severely stunted children. Only 20 % of the severely stunted children at age 1 recovered between 1 and 5 years of age. This compares with 44 % of the children who were not severely stunted at age 1. Recovery was more pronounced in children from households that did not experience food shortage compared to children from households that experienced food shortage (37 vs 17 %). Compared to their counterparts, recovery was more in children who consumed fruit or meat during the last 24 hours, who had no sibling, whose mothers were average/tall, whose mothers had 5 or more years of schooling, and whose mothers were involved in household work. Recovery was also associated with the change in wealth status of the households between waves one and two. Recovery was highest (48 %) in children from households who were on or above the poverty point in both the waves. Recovery was also dramatic in children from households who were below

Table 2 Determinants of stunting among 1965 young children: results of logistic regression

Variables	OR	95 % CI
Birth size		
Small®	1.00	
Average	0.61*	0.48–0.79
Large	0.47*	0.36–0.62
Premature birth		
No®	1.00	
Yes	1.45*	1.02–2.03
Age of child (in months)	1.11*	1.08–1.14
Sex of child		
Male®	1.00	
Female	0.69*	0.56–0.85
Child ever breastfed		
Yes®	1.00	
No	0.86	0.44–1.68
Number of siblings		
0®	1.00	
1	0.91	0.71–1.17
≥2	1.49*	1.12–1.97
Mother's years of schooling		
0–4 years®	1.00	
≥5 years	0.95	0.73–1.24
Mother's working status		
Household work®	1.00	
Others	1.20	0.95–1.52
Mother's height		
Short <145 cm®	1.00	
Average/tall ≥145 cm	0.41*	0.30–0.55
Mother's age at birth of child		
<18 years®	1.00	
≥18 years	0.52*	0.36–0.74
Mother received antenatal check-up		
<4 ANC®	1.00	
≥4 ANC	0.87	0.68–1.11
Mother consumed iron folic acid supplementation		
<3 months®	1.00	
≥3 months	1.02	0.71–1.45
Mother received tetanus injection		
<2 TT®	1.00	
≥2 TT	1.12	0.73–1.72
Years of schooling of the household head		
0–4 years®	1.00	
≥5 years	0.78*	0.61–1.00
Caste		
Scheduled tribes®	1.00	
Scheduled castes	0.78	0.55–1.11
Other backward classes	0.67*	0.50–0.92
Others	0.48*	0.32–0.72

Table 2 continued

Variables	OR	95 % CI
Wealth index		
Poor®	1.00	
Middle	0.71*	0.55–0.92
Rich	0.67*	0.46–0.98
Toilet facility		
Improved®	1.00	
Non-improved	1.53*	1.02–2.29
Drinking water		
Safe®	1.00	
Unsafe	0.91	0.68–1.21
Place of residence		
Rural®	1.00	
Urban	1.20	0.83–1.76

® Reference, * $p < 0.05$

the poverty point in wave one but were on or above the poverty point in wave two (44 %). Recovery was least in children from households that were below the poverty point in both the waves (27 %). Compared to their counterparts, recovery was also higher in children from households using safe drinking water and improved toilet facility. Recovery was also likely to be high in children from urban than children from rural areas.

Results of logistic regression examining the factors associated with the likelihood of recovery from stunting between 1 and 5 years are shown in Table 4. The likelihood of recovery was statistically associated with severity of stunting even after adjusting for all other important variables. Children who were not severely stunted were 3.06 (95 % CI 1.99–4.69) times as likely as severely stunted children to recover. Consumption of fruit was also statistically associated with recovery. Children who reported having consumed fruit in the last 24 hours were 1.53 (95 % CI 1.01–2.31) times as likely as children who did not consume fruit to recover. Food shortage was also statistically associated with low recovery. Children from households that experienced food shortage were 0.45 (95 % CI 0.20–0.98) times as likely as children from households that did not experience food shortage to recover. Interestingly, the recovery also depended on the height of the mother. Children whose mothers were average/tall were more likely than children whose mothers were short to recover (OR 1.87; 95 % CI 1.25–2.78). Change in wealth status of the household was also statistically associated with recovery. Children from households who were on or above the poverty point in both the waves were more likely than children from households who remained below the poverty point in both waves to recover (OR 2.01; 95 % CI 1.07–3.75). Likewise, children from households who were below the poverty point in wave one but were on or above the poverty point in wave two were 1.79 (95 % CI 1.04–3.08) times as likely as children from households who were below the poverty point in both waves to recover. Recovery was also more likely to occur in children residing in urban than in rural areas (OR 2.60; 95 % CI 1.40–4.82).

Recovery from stunting between 5 and 8 years are shown in Table 5. Of the 670 children that were stunted at age 5 years about 30 % children recovered by age 8. Again, the severity of stunting was associated with recovery between 5 and 8 years. Only 8 % severely stunted children recovered. In comparison, 35 % of other children recovered. As found earlier, recovery from stunting between 5 and 8 years was also associated with child immunization, mother's height, mother's schooling, mother's working status, type of toilet facility and place of residence.

In the multivariable analysis, severe stunting ($-3SD \leq HAZ < -2SD$) at age 5 was statistically associated with recovery between 5 and 8 years (Table 6). Children who were not severely stunted were 6.07 (95 % CI 3.03–12.17) times as likely as severely stunted children to recover. Child immunization was another variable that was statistically associated with recovery – children who had received full immunization were 2.35 (95 % CI 1.05–5.26) times as likely as children who had received no/partial immunization to recover from stunting. Mother's height (OR 2.03; 95 % CI 1.39–2.96) and place of residence (OR 1.90; 95 % CI 1.05–3.45) were also statistically associated with recovery even after adjusting for other independent variables.

Discussion

Childhood malnutrition is a serious public health problem in India. The recent estimates from the National Family Health Survey (NFHS) 2005–2006 suggest that about 48 % of children under age 5 years are stunted in India (IIPS and ORC Macro 2007). India alone accounts for more than 60 million stunted children. Our findings indicate that birth size has a significant impact on early childhood stunting in India, independent of pre-mature birth, age, gender, mother's schooling, mother's working status, household wealth and other factors. To the best of our knowledge, this is the first representative study that examines the impact of birth size on childhood stunting in India. Our findings are consistent with the findings of an earlier small-scale study conducted in India (Rehman et al. 2009). There is a need to counsel women on the nutritional need of pregnant women. Recent data from District Level Household Survey (DLHS) 2007–2008 suggests that only 57 % of the pregnant women

Table 3 Percentage of children who recovered from stunting between 1 and 5 years

Variable	Remained stunted (n = 377)	Recovered (n = 205)	Chi^2 (p val.)	Number
Height for age z-score				
HAZ < −3SD	79.8	20.2	26.5 (0.00)	213
−3SD ≤ HAZ < −2SD	56.1	43.9		369
Premature birth				
No	64.4	35.6	0.44 (0.51)	517
Yes	67.7	32.3		65
Sex of child				
Male	65.5	34.5	0.11 (0.74)	345
Female	63.7	36.3		237
Milk consumed				
No	64.8	35.2	0.05 (0.82)	247
Yes	64.8	35.2		335
Fruit consumed				
No	68.5	31.5	6.30 (0.01)	384
Yes	57.6	42.4		198
Egg consumed				
No	65.0	35.0	0.00 (0.98)	488
Yes	63.8	36.2		94
Fish consumed				
No	64.7	35.3	0.10 (0.75)	552
Yes	66.7	33.3		30
Meat consumed				
No	65.7	34.3	2.62 (0.11)	539
Yes	53.5	46.5		43
Food shortage				
No	62.8	37.2	9.1 (0.003)	524
Yes	82.7	17.2		58
Immunization				
No/partial	65.3	34.7	0.01 (0.92)	49
Full	64.7	35.3		533
Number of siblings				
0	56.0	44.0	1.36 (0.51)	50
1	61.3	38.7		279
≥2	70.4	29.6		253
Mother's height				
Short <145 cm	70.1	29.9	4.92 (0.03)	288
Average/tall ≥145 cm	59.5	40.5		294
Mother's age at birth of child				
<18 years	61.3	38.7	3.15 (0.26)	75
≥18 years	65.3	34.7		507
Mother's years of schooling				
0–4 years	68.0	32.0	3.15 (0.08)	422
≥5 years	56.2	43.8		160
Mother's working status				
Household work	59.3	40.7	5.26 (0.02)	231
Others	68.4	31.6		351

Table 3 continued

Variable	Remained stunted (n = 377)	Recovered (n = 205)	Chi^2 (p val.)	Number
Years of schooling of the household head				
0–4 years	67.8	32.2	13.08 (0.00)	366
≥5 years	59.7	40.3		216
Caste				
Scheduled tribes	58.6	41.4	1.42 (0.49)	116
Scheduled castes	66.1	33.9		115
Other backward classes	68.2	31.8		277
Others	59.5	40.5		74
Change in wealth status				
Always below the poverty point	72.6	27.4	20.01 (0.00)	318
Household moved from below poverty point to on or above the poverty point	55.8	44.2		95
Household moved from on or above poverty point to below poverty point	65.6	34.4		32
Always on or above the poverty point	52.5	47.5		137
Toilet facility				
Improved	59.7	40.3	0.78 (0.38)	77
Non-improved	65.5	34.5		505
Drinking water				
Safe	63.7	36.3	2.96 (0.09)	538
Unsafe	77.3	22.7		44
Place of residence				
Rural	68.5	31.5	19.96 (0.00)	480
Urban	47.1	52.9		102
Total	64.8	35.2		582

This table is based on 582 children of age 1 who were stunted

were counselled on the importance of nutrition during pregnancy (IIPS 2010).

Mother's height was also a significant predictor of early childhood stunting. This finding clearly reflects on the intergenerational mobility of malnutrition from mother to her baby (Ramakrishnan et al. 1999; UNICEF 1998). Mother's height might also affect childhood stunting due to genetic and other endowments (Bosch et al. 2008; Ozaltin et al. 2010; Subramanian et al. 2009). Another key finding is the association between type of toilet facility and stunting among children. Children from households using non-improved toilets were 1.53 times as likely as children from households using improved toilets to be stunted. This finding is also consistent with the findings of previous studies conducted in India (Robert and Gregar 2013; Spears et al. 2013). Poor sanitation may be associated with poor nutritional outcome via a number of pathways, including diarrhea (Checkley et al. 2008) and gastrointestinal disorders (Haghighi and Wolf 1997; Humphrey 2009). A study among children in rural Bangladesh has shown that children who are exposed to worst sanitation show indicators of enteropathy (Lin et al. 2013).

Our analysis further shows that more than 35 % of stunted children recovered between 1 and 5 years. The percentage of stunted children who recovered from early childhood stunting is consistent with the findings from previous studies (Adair 1999; Berkman et al. 2002; Lundeen et al. 2014; Mendez and Adair 1999; Vella et al. 1994). In an analysis of 2011 Filipino children, more than 29 % of stunted children experienced recovery by age 8.5 year (Adair 1999). Another study, among Peruvian children in Lima, showed that more than 50 % of the 239 children that were stunted in first 2 years recovered (Berkman et al. 2002). One more study among Peruvian children showed that about 34 % of stunted children recovered by the age of 8 years (Checkley et al. 2003). These studies used similar methods for collecting anthropometric data and defining recovery. Notably, the magnitude of recovery in our sample is nearly identical to that reported by Checkley et al. (2003). In addition, 30 % of the stunted children at age 5 recovered between 5 and 8 years. Our study is perhaps the first study in India that has examined the determinants of the likelihood of recovery from stunting between ages 1 and 5 years and between 5 and 8 years.

Table 4 Determinants of the likelihood of recovery from stunting between 1 and 5 years: results of logistic regression

Variable	OR	95 % CI
Height for age z-score		
HAZ < −3SD®	1.00	
−3SD ≤ HAZ < −2SD	3.06*	1.99,4.69
Premature birth		
No®	1.00	
Yes	0.67	0.35,1.26
Age of child	1.08*	1.03,1.14
Sex of child		
Male®	1.00	
Female	1.08	0.74,1.59
Milk consumed		
No®	1.00	
Yes	0.72	0.47,1.11
Fruit consumed		
No®	1.00	
Yes	1.53*	1.01,2.31
Egg consumed		
No®	1.00	
Yes	0.92	0.55,1.56
Fish consumed		
No®	1.00	
Yes	0.73	0.30,1.77
Meat consumed		
No®	1.00	
Yes	1.65	0.80,3.38
Food shortage		
No®	1.00	
Yes	0.45*	0.20,0.98
Immunization		
No/partial®	1.00	
Full	1.35	0.67,2.75
Number of siblings		
0®	1.00	
1	0.65	0.32,1.32
≥2	0.49*	0.24,0.99
Mother's height		
Short <145 cm®	1.00	
Average/tall ≥145 cm	1.87*	1.25,2.78
Mother's age at birth of child		
<18 years®	1.00	
≥18 years	0.84	0.48,1.47
Mother's years of schooling		
0–4 years®	1.00	
≥5 years	1.05	0.64,1.73
Mother's working status		
Household work®	1.00	
Others	0.82	0.53,1.25

Table 4 continued

Variable	OR	95 % CI
Years of schooling of the household head		
0–4 years®	1.00	
≥5 years	1.02	0.65,1.58
Caste		
Scheduled tribes®	1.00	
Scheduled castes	0.44*	0.24,0.81
Other backward classes	0.33*	0.19,0.58
Others	0.29*	0.14,0.64
Change in wealth status		
Always below the poverty point®	1.00	
Household moved from below poverty point to on or above the poverty point	1.79*	1.04,3.08
Household moved from on or above poverty point to below poverty point	1.38	0.60,3.21
Always on or above the poverty point	2.01*	1.07,3.75
Toilet facility		
Improved®	1.00	
Non-improved	1.71	0.91,3.22
Drinking water		
Safe®	1.00	
Unsafe	0.50	0.22,1.15
Place of residence		
Rural®	1.00	
Urban	2.60*	1.40,4.82

® Reference, * $p < 0.05$

Interestingly, the recovery from early childhood was higher between 1 and 5 years than between 5 and 8 years (35 % vs 30 %). Furthermore, age of the children was statistically and positively associated with recovery only between 1 and 5 years (OR 1.08; 95 % CI 1.03–1.14). These findings clearly indicate that the chance of recovery diminishes as the child progresses with age, with maximum recovery possible during 1–5 years of age. This finding is consistent with previous research linking distal and community factors with period of child growth up to the age of 8 years (Schott et al. 2013). Hence, any policy intervention during 0–5 years of age is likely to yield higher benefits in terms of recovery than interventions focussing on higher ages.

Severely stunted children were significantly less likely to recover than other stunted children. Earlier studies have also reported that higher HAZ at baseline increases the probability of recovery (Adair 1999; Crookston et al. 2010; Lundeen et al. 2014; Mendez and Adair 1999; Tanner 1981). In a study of 2011 Filipino children, children who were less severely stunted at the baseline were more likely to recover than severely stunted children (Adair 1999). One more study among Filipino children reported similar findings (Mendez and Adair 1999). Another study that uses longitudinal data among 1674 Peruvian children also reported that the catch up growth was two times higher among children who were less severely stunted during infancy as compared to the children who were severely stunted (Crookston 2010). Interestingly, mother's height was also statistically associated with recovery—children of average height/taller mothers showed higher likelihood of recovery between 1 and 5 years, and between 5 and 8 years. Similar finding was also reported by a number of previous studies (Adair 1999; Addo et al. 2013; Schott et al. 2013). Study from rural Ethiopia reported that maternal height was significantly associated with stunting and recovery from stunting by age 1 year, 5 year and 8 year (Outes and Porter 2013). Adiar (1999) also reported similar finding in a study among Filipino children.

Change of wealth status was statistically associated with recovery between 1 and 5 years. Interestingly, children from households who were below the poverty point in wave one but were on or above the poverty point in wave two had a greater propensity to recover than children from households that were below poverty point in both the waves. Outes and Porter (2013) also found higher rate of catch-up among children from better-off households

Table 5 Percentage of children who recovered from stunting between 5 and 8 years

Variable	Remained stunted (n = 471)	Recovered (n = 199)	Chi^2 (p val.)	Number
Height for age z-score				
HAZ < −3SD	92.3	7.7	26.93 (0.00)	130
−3SD ≤ HAZ < −2SD	65.0	35.0		540
Premature birth				
No	70.4	29.6	0.23 (0.63)	614
Yes	69.6	30.4		56
Sex of child				
Male	72.4	27.6	0.81 (0.37)	377
Female	67.6	32.4		293
Immunization				
No/partial	80.0	20.0	3.50 (0.06)	50
Full	69.5	30.5		620
Change in energy intake				
Low, no change in energy intake	74.3	25.7	1.20 (0.75)	35
Low, increase in energy intake	67.5	32.5		126
High, decrease in energy intake	70.6	29.4		51
High, no change in energy intake	70.7	29.3		458
Food shortage				
No	69.2	30.8	0.08 (0.77)	471
Yes	70.4	29.6		199
Number of siblings				
0	71.4	28.6	7.37 (0.03)	35
1	63.3	36.7		313
≥2	77.0	23.0		322
Mother's height				
Short <145 cm	78.0	22.0	8.79 (0.00)	341
Average/tall ≥145 cm	62.3	37.7		329
Mother's age at birth of child				
<18 years	70.4	29.6	0.03 (0.86)	71
≥18 years	70.3	29.7		599
Mother's years of schooling				
0–4 years	73.0	27.0	9.71 (0.00)	482
≥5 years	63.3	36.7		188
Mother's working status				
Household work	63.4	36.6	6.57 (0.01)	273
Others	75.1	24.9		397
Years of schooling of the household head				
0–4 years	72.7	27.3	3.82 (0.05)	403
≥5 years	66.7	33.3		267
Caste				
Scheduled tribes	81.8	18.2	12.26 (0.00)	99
Scheduled castes	72.5	27.5		131
Other backward classes	67.2	32.8		345
Others	66.3	33.7		95
Change in wealth status				
Always below the poverty point	79.1	20.9	23.04 (0.00)	277
Household moved from below poverty point to on or above the poverty point	69.6	30.4		142

Table 5 continued

Variable	Remained stunted (n = 471)	Recovered (n = 199)	Chi^2 (p val.)	Number
Household moved from on or above poverty point to below poverty point	69.0	31.0		23
Always on or above the poverty point	60.5	39.5		228
Toilet facility				
Improved	60.7	39.3	6.39 (0.01)	107
Non-improved	72.1	27.9		563
Drinking water				
Safe	70.4	29.6	0.00 (0.95)	645
Unsafe	68.0	32.0		25
Place of residence				
Rural	73.0	27.0	18.85 (0.00)	556
Urban	57.0	43.0		114
Total	70.0	30.0		670

This table is based on 670 children who were stunted at age 5

compared with children from poorer households. Vella et al. (1994) found a significant effect of household economic status on linear growth of children. Another factor that was statistically associated with recovery between 1 and 5 years was the consumption of fruit. Children who reported consuming fruit in the 24-hours recall period were more likely to recover than children who did not consume fruit (OR 1.53; 95 % CI 1.01–2.31). Sedgh et al. (2000) found that carotenoids rich diet increases the rate of recovery among the stunted children in Uganda. In comparison, child immunization was statistically associated with recovery between 5 and 8 years—fully immunized children had a greater likelihood of recovery compared to children who were partially immunized or not immunized at all. This finding is similar to the finding of Anekwe and Kumar (2012) who reported that Universal Immunization Program has improved the prospect of child growth in India. Our study clearly shows that efforts – like hygiene and childhood vaccinations–to prevent illnesses can go a long way in reducing malnutrition in the country.

Although the access to toilet facility was statistically associated with stunting, it was not statistically associated with recovery between 5 and 8 years. Similarly, the access to safe water was also not statistically associated with recovery from stunting between 5 and 8 years. These findings should not be surprising given the fact that about 84 % of the households were using safe water in wave 1 of the YLS. The access to safe water increased from 84 % to more than 90 % in waves 2 and 3 (Results not shown). On the contrary, the access to a toilet facility was limited. Only 18 % of the households in wave 1 had access to improved toilets. Notably, we could not examine the effect of improvement in access to improved toilets on recovery from stunting between 5 and 8 years. This was due to small number of households that switched from unimproved toilets to improved toilets between the three waves. Our findings are consistent with the findings of Adair (1999) who also did not find any association between piped water and recovery from stunting.

This study has some limitations. First, there is no standard definition of recovery. In general, the term 'recovery' refers to acceleration in growth after a period of growth retardation. Therefore, the magnitude of recovery presented in the paper might depend on the definition of recovery. To make our results comparable with the findings of the previous studies, we have used the same definition of recovery (Adair 1999; Crookston et al. 2010; Mendez and Adair 1999; Tanner 1981). Second, the magnitude of recovery between 1 and 5 years may be somewhat overstated in our sample because we were unable to examine the recovery from exact age 2 year to represent recovery in early childhood (Growth retardation starts at time of conception and most growth retardation takes place by the of age 2 years) due to data limitation. However, a study done in Guatemala, in which multiple anthropometric measurements were taken over the first 7 years of age, shows that HAZ at age 6 to 18 months predict well HAZ at age 24 months (for age 6, 12 and 18 months, correlation with HAZ at 24 months were r = 0.74, 0.83 and 0.91 respectively) (Schott et al. 2013). If similar correlations across ages also hold in the YLS sample, then pattern of HAZ in our sample will fairly represent HAZ of these children at age of 24 months. Third, we used birth size as a proxy of birth weight. We could not use birth weight because the information on birth weight was available for only 43 % children recruited in YLS. The inclusion of birth size as a

Table 6 Determinants of the likelihood of recovery from stunting between 5 and 8 years: results of logistic regression

Variable	OR	95 % CI
Height for age z-score		
HAZ < −3SD®	1.00	
−3SD ≤ HAZ < −2SD	6.07*	3.03,12.17
Premature birth		
No®	1.00	
Yes	1.35	0.69,2.64
Age of child (in months)	1.00	0.95,1.04
Sex of child		
Male®	1.00	
Female	1.34	0.93,1.94
Immunization		
No/partial®	1.00	
Full	2.35*	1.05,5.26
Change in energy intake		
Low, no change in energy intake®	1.00	
Low, increase in energy intake	1.23	0.75,2.02
High, decrease in energy intake	0.88	0.49,1.58
High, no change in energy intake	1.10	0.46,2.62
Food shortage		
No®	1.00	
Yes	1.04	0.69,1.55
Number of siblings		
0®	1.00	
1	1.05	0.46,2.41
≥2	0.66	0.29,1.54
Mother's height		
Short <145 cm®	1.00	
Average/tall ≥145 cm	2.03*	1.39,2.96
Mother's age at birth of child		
<18 years®	1.00	
≥18 years	0.89	0.49,1.62
Mother's years of schooling		
0–4 years®	1.00	
≥5 years	1.06	0.68,1.65
Mother's working status		
Household work®	1.00	
Others	0.77	0.52,1.14
Years of schooling of the household head		
0–4 years®	1.00	
≥5 years	0.83	0.55,1.26
Caste		
Scheduled tribes®	1.00	
Scheduled castes	1.52	0.76,3.07
Other backward classes	1.54	0.82,2.87
Others	1.21	0.56,2.62
Change in wealth status		
Always below the poverty point®	1.00	
Household moved from below poverty point to on or above the poverty point	1.08	0.39,3.03

Table 6 continued

Variable	OR	95 % CI
Household moved from on or above poverty point to below poverty point	1.44	0.87,2.40
Always on or above the poverty point	1.59	0.94,2.68
Toilet facility		
Improved®	1.00	
Non-improved	0.93	0.52,1.66
Drinking water		
Safe®	1.00	
Unsafe	1.65	0.62,4.40
Place of residence		
Rural®	1.00	
Urban	1.90*	1.05,3.45

® Reference, * $p < 0.05$

proxy of birth weight should not affect our estimates significantly because previous studies have shown that birth size is a good proxy of birth weight in developing countries setting (Titaley et al. 2010). Another point to be noted is that the YLS covers samples only from Andhra Pradesh. So, there might be issues with the generalizability of YLS findings to larger Indian population. A comparison of YLS with the second round of NFHS 1998–1999 suggests that the YLS sample in Andhra Pradesh covers the diversity of children in the country. In addition, studies have concluded that the YLS sample in Andhra Pradesh is an appropriate and valuable instrument for analyzing causal relationship and modelling child welfare (Galab et al. 2008).

Despite these limitations, this study has a number of strengths. First a large cohort of children was included in the study. Second the cohort of children was followed-up over waves. This provided us with an opportunity to analyze the association between birth size and stunting in a systematic manner. This also provided us an opportunity to analyze the factors associated with recovery from early childhood stunting. Interestingly, we were also in a position to examine the effect of change in wealth status of the household on recovery. Third, we could control for repeated measures of dietary intake of child, socio-economic status and household amenities. Finally, our study came out with some findings that may either lead to formulation of new policies or may lead to the strengthening of the existing policies and programmes.

This study has contributed to the understanding of the impact of birth size on childhood stunting and the extent of recovery from early childhood stunting in India. Our findings call for greater focus on maternal health and nutrition during pregnancy and after delivery. The consumption of fruit and regular supply of food grains throughout the year is likely to help children recover from early stunting between 1 and 5 years. In comparison, child immunization is likely to help children recover from stunting between 5 and 8 years. Improving sanitation and hygiene is also likely to go a long way in reducing early childhood stunting in India. Improvement in maternal schooling and regular income, and a greater focus on family planning and child health related programmes can be the important strategies that the Government of India can pursue to address malnutrition among children in India. Furthermore, the follow-up of the children beyond age 8 years is necessary to demonstrate what happens to the nutritional status of these children during their adolescence and adulthood.

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