Original Article

Determinants of stunting reduction in Ethiopia 2000–2011

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Abstract

The prevalence of stunting in Ethiopia declined from 57% in 2000 to 44% in 2011, yet the factors producing this change are not fully understood. Data on 23,999 children 0–59 months of age from three Demographic and Health Surveys (DHS) from 2000, 2005, and 2011 were analyzed to assess the trends in stunting prevalence, mean height-for-age z-scores (HAZ) and the associations between potential factors and HAZ. Associations were determined separately using three separate generalized linear models for children age less than 6 months, 6–23 months, and 24–59 months of age. Significant variables were then analyzed to determine if they showed an overall trend between the 2000 and 2011 surveys. In children < 6 months of age, only mother's height was both a significant predictor of HAZ and showed a progressive, albeit non-significant, increase from 2000 to 2011. In children 6–23 months of age, only mother's use of modern contraception showed substantial changes in a direction consistent with improving HAZ, but improvements in maternal nutrition status were observed from 2000 to 2005. For children 24–59 months of age a consistent and progressive change is seen in child's diarrhea, fever, mother's education, and the occurrence of open defecation. Our analysis demonstrated that factors associated with HAZ vary by child's age and the dominant livelihood practice in the community. Variables that could have contributed to the decline of stunting in Ethiopia in children less than 5 years of age include markers of child health, mother's nutritional status, mother's educational level, and environmental hygiene.

Keywords: stunting, stunting reduction, growth, HAZ, determinants, risk factors, Ethiopia.

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Introduction

Stunting, or suboptimal growth by age in children < 5 years old, is associated with adverse short- and long-term health outcomes. In the short-term, the consequences of stunting include an increased risk of infectious diseases and poor psychomotor and mental development (Abubakar *et al.* 2010; McDonald *et al.* 2012). In the long term, childhood stunting has been linked to obesity and diabetes (Bhargava *et al.* 2004) and lower human capital in adulthood (Victora *et al.* 2008).

Reducing the prevalence of stunting is one of the World Health Assembly's Nutrition Targets for 2025 (40% reduction in the number of under five children stunted) (WHO 2012). Globally, stunting has declined by 1.8% annually between 1995 and 2010, with some

countries observing annual reductions of 3.9% or higher in this time period (de Onis *et al.* 2013). In Ethiopia, stunting has declined on average by 1.2% per year since 2000. Though the annual rate of stunting reduction in Ethiopia is below the global average, Ethiopia's stunting reduction is noteworthy as it is one of the few African countries to substantially reduce the prevalence and the number of stunted children in the past two decades (de Onis *et al.* 2013). According to UNICEF (2013a), child stunting in Ethiopia was reduced by more than 20 percentage points in the past 20 years. As measured in a series of Demographic and Health Surveys (DHS) using comparable methodologies, the prevalence of stunting declined from 57% in 2000 to 51% in 2005 and 44% 2011 (Central Statistical Authority [Ethiopia] and ICF International 2012). Nonetheless, the prevalence of stunting in Ethiopia remains somewhat

higher than the regional prevalence of 40% in east and southern Africa (UNICEF 2013b).

This analysis has been conducted to understand the reasons for the reduction in stunting between 2000 and 2011 in Ethiopia. It identifies factors that are associated with HAZ overall and have changed during this time period. These results may be useful in identifying factors for future interventions to further reduce the prevalence of stunting in Ethiopia. In addition, the methods used in this analysis could be used in other sub-Saharan countries to identify factors contributing to stunting in order to design and adjust programs addressing stunting.

Methods

Data sources

Ethiopia's three nationwide DHS, conducted in 2000, 2005, and 2011, served as the main source of data for this analysis. These surveys are representative at both the national and regional level; the design of these DHS is presented in further detail elsewhere (Central Statistical Authority [Ethiopia] and ORC Macro 2001, Central Statistical Authority [Ethiopia] and ORC Macro 2006, Central Statistical Authority [Ethiopia] and ICF International 2012).

In each DHS, anthropometric measurements were taken on children 0–59 months. In the 2000 and 2011 DHS, all children in all selected households were recruited for measurement. In the 2005 survey, children were recruited for measurement only in a randomly selected subsample of ½ of the recruited households. Hence, the number of children with weight and height measurements is much smaller in the 2005 survey than in the other two DHS. Length and height measurements of

children were made using standard procedures, and using length/height, weight, and age information from children in all rounds, length/height-for-age z-scores (HAZ) and weight-for-height z-scores (WHZ) were calculated using the WHO Child Growth Standard (WHO Multicentre Growth Reference Study Group 2006).

Stunting was defined as having a HAZ less than -2.0; children with $HAZ \geq -2.0$ are considered non-stunted. Children without valid measurements of length or height or age were excluded from all analyses. As widely recommended, children with HAZ less than -6.0 or greater than +6.0 were excluded from all analyses (SMART 2006).

Enumeration areas (EA) were assigned to livelihood zones so that results could be presented according to four sub-national groups: urban, rural-agricultural, rural-agro-pastoral, and rural-pastoral. EAs were classified as urban based on DHS classifications, and rural areas were sub-divided based on the governmental classification (USAID & Government of Ethiopia 2011).

Selection of factors potentially associated with growth

The recently-published WHO conceptual framework on childhood stunting (Stewart *et al.* 2013) was used to identify the most comprehensive set of factors potentially associated with stunting. Using this framework, the three DHS datasets, DHS reference materials, dataset maps, and data collection forms were thoroughly reviewed in order to select variables included in the DHS which may be considered potential contributory factors to a stunting reduction in Ethiopia. A literature review examining existing knowledge of the contributors to child stunting in Ethiopia and indicators available in the DHS was also

Key messages

- The factors associated with HAZ vary by child's age and the dominant livelihood practice in the community.
- Few factors were associated with HAZ in children <6 months of age, and no factors were both statistically significantly associated with HAZ and consistently improved since 2000.
- For children 6–23 months of age, improvements in HAZ were statistically significantly associated only with mother's use of modern contraception.
- For children 24–59 months of age, improvements in HAZ were consistently associated with improvements in mother's education and reductions in child's diarrhea, fever, and the occurrence of open defecation.

conducted to identify additional potential contributory factors (Wirth *et al.* 2013). WHZ, although not included in the WHO conceptual framework, was included in the analysis because, in addition to wasting sharing risk factors with stunting, there is some evidence that wasting itself may be a direct and independent cause of stunting (Khara & Dolan 2014).

In total, 83 potential factors were identified. In addition to values provided directly in the DHS data files, a new household wealth index was calculated on pooled data from all survey rounds using principal component analysis of the same variables used in the original DHS calculation (Rutstein & Johnson 2004). This allowed assessment of trends in household wealth between 2000 and 2011.

Data analysis

Data analysis was conducted in three phases. First, a bivariate analysis using pooled data from all three DHS was conducted to identify those variables which were associated with HAZ in Ethiopia. Continuous and categorical variables were analyzed using linear regression and ANOVA, respectively, against HAZ as a continuous outcome. Linear data analysis techniques were used because associations using continuous data generally have more statistical precision than analysis of a categorized form of a continuous variable. Pooled data was used to maximize the number of children

included in each bivariate analysis, thus increasing the precision and likelihood of detecting an association with statistical significance. Sampling weights were not used in this bivariate analysis.

Second, a national-level multivariate linear regression analysis was conducted on the pooled data from all three surveys. Separate models were constructed for three different age groups – children <6 months of age, children 6–23 months of age, and children 24–59 months of age – because potential risk factors and feeding patterns in young children differ substantially by age and DHS collect different data on children of different ages. Each model included variables that were statistically significantly associated with HAZ in the bivariate pooled analysis and were measured in all three surveys. Factors identified in a literature review of stunting determinants in Ethiopia (Wirth *et al.* 2013) strongly related to stunting in Ethiopia as well as variables of high interest, such as exclusive breastfeeding, child age, and child sex, were also included in the initial models regardless of the apparent strength of their association with HAZ in the bivariate analysis. In addition, survey year was included in the model to represent unmeasured factors not captured by the other explanatory variables that could have changed over time. Using the national-level model, backward elimination was used to remove variables which did not make a statistically significant ($p < 0.05$) contribution. Those

Table 1. Selected information about the three DHS included in our data analysis

Survey	Dates of data collection	Number of households	Children 0–59 months of age	Number of children with valid HAZ*	HAZ*	National prevalence of stunting	P-value
		n (% response)	n	n	mean	(%)	
DHS 2000	February – May 2000	14,072 (96.1%) of 14,642 selected households	9,513	9,417	-2.08	57.7	<0.001
DHS 2005	April – August 2005	13,721 (93.7%) of 14,645 selected households	4,455 [†]	4,141 [†]	-1.78	50.8	
DHS 2011	Dec 2010 – June 2011	16,702 (93.7%) of 17,818 selected households	10,480	10,441	-1.61	44.3	
Total	n/a	n/a	24,448	23,999	n/a	n/a	

*Height-for-age z-score

[†]Children were weighed and measured in only one-half of selected households.

n/a = not applicable

variables remaining in the final, most parsimonious national model were then included in separate models for each livelihood zone. Removal of WHZ from regression analyses did not change resulting regression coefficients.

Third, a trends analysis of variables in each final model was undertaken to identify variables that significantly changed between the three DHS and may thus have contributed to the decline in stunting in Ethiopia from 2000–2011. The weighted mean values (for continuous variables) or weighted prevalence (for categorical values) were compared among the three DHS. Statistical difference was determined using ANOVA or adjusted chi square.

In all phases, statistical significance was defined as a *p* value less than 0.05. All analyses except the initial bivariate analyses used sampling weights already contained in the DHS databases. Calculation of all estimates of precision (e.g. *p* values, confidence intervals, etc.) took into account the complex sampling used in DHS, including cluster sampling and stratification. All statistical analyses were conducted using SPSS version 21.

Results

Trends in stunting

Table 1 shows the dates of data collection and the number of households and children included in the analyses in each DHS. In total, 98.2% of children less than 5 years of age had weight, height, and age measurements resulting in a valid HAZ. The mean HAZ in all children increased by 0.47 standard deviations between 2000 and 2011.

In each DHS, the mean HAZ differs significantly by age group; children <6 months of age had the highest mean HAZ and children 24–59 months old had the lowest mean HAZ. Mean HAZ also improved from 2000 and 2011 in all age groups. The total increase in HAZ during this time period was slightly greater in children 0–5 months of age and children 6–23 months of age (0.66 and 0.65 *z*-scores, respectively) than in children 24–59 months of age (0.49 *z*-scores). By 2011, the mean HAZ for the youngest age group was -0.06; close to a distribution with the mean of 0.

Bivariate analyses

The results of the unweighted bivariate analysis of the association between various factors and HAZ are shown in supplementary table 1. Many variables are statistically significantly associated with HAZ. Some variables, however, were not collected in all three surveys or were not collected in a standardized fashion allowing comparison among the three surveys. Such variables were excluded from subsequent data analysis.

Multivariate and trend analyses – children

<6 months of age

Table 2 presents the regression results for all children <6 months of age. The residuals for this model are normally distributed and not correlated with the predicted HAZ (results not shown). This model accounts for 27.8% of the variability in HAZ in this age group ($R^2 = 0.278$). Significant predictors of HAZ include child sex, age, estimated birth size, WHZ, mother's height, and household wealth. Mean HAZ is significantly lower in boys than girls, and HAZ declines significantly with increased age. Although estimated birth size is a crude measure of birth weight, it is strongly associated with HAZ and shows a dose-response relationship; the smaller the mother's estimate of birth size, the lower the HAZ (results not shown). A child's WHZ is significantly inversely related to that child's HAZ. Mother's height and household wealth show a significant and positive association with HAZ.

Livelihood-specific models account for a similar or higher variability in HAZ as the overall model, with the pastoral model accounting for nearly 49.7% of the variance in HAZ. Moreover, the importance of each independent variable varies among the livelihood-specific models. The sex difference in mean HAZ is much lower in urban and agro-pastoral areas than in rural-agricultural and rural-agro-pastoral communities; however, in some livelihood groups, a relatively small number of children may make estimates somewhat imprecise. Child's age was much less strongly related to HAZ in agro-pastoral and pastoral communities. Unlike child's age and sex, estimated birth size remained statistically significant in all models. Although the association between HAZ and child's WHZ and mother's height was not statistically significant in all models, the

Table 2. Linear regression model with HAZ as outcome which includes only children <6 months of age and only variables collected in all three DHS; applied to each of four livelihood zone categories; national

Variable	National (n=2,031; R ² =0.278)		Urban (n=304; R ² =0.365)		Agricultural (n=1,399; R ² =0.269)		Agro-pastoral (n=153; R ² =0.318)		Pastoral (n=136; R ² =0.497)		Comparison of survey results			
	β coeff- icient [†]	P value [†]	β coeff- icient [†]	P value [†]	β coeff- icient [†]	P value [†]	β coeff- icient [†]	P value [†]	β coeff- icient [†]	P value [†]	2000	2005	2011	p value
Child's sex [‡]		.006		0.093		0.021		0.807		0.119				0.700
Male	-0.25		-0.39		-0.23		-0.42		-0.44		52.3%	56.0%	52.7%	
Female	referent		referent		referent		referent		referent		47.7%	44.0%	47.3%	
Child's age	-0.22	<.001	-0.20	0.030	-0.25	<.001	0.003	0.969	0.06	0.519	2.79	2.99	2.80	0.179
(in months) [§]														
Child's estimated size at birth [‡]		<.001		<.001		<.001		0.073		0.630				<.001
Very large	0.84		1.11		0.91		1.30		0.66		3.0%	16.0%	18.1%	
Larger than average	0.62		0.86		0.57		1.12		0.62		18.9%	3.3%	11.7%	
Average	0.60		0.89		0.57		0.85		1.02		35.3%	45.1%	34.4%	
Smaller than average	-0.07		-1.24		0.04		0.19		0.46		34.9%	9.7%	10.2%	
Very small	referent		referent		referent		referent		referent		7.9%	25.9%	25.7%	
Child's weight-for- height z-score [§]	-0.43	<.001	-0.34	<.001	-0.43	<.001	-0.23	0.152	-0.55	<.001	-0.25	-0.10	-0.42	0.092
Mother's height (in cm) [§]	0.04	<.001	0.04	0.066	0.04	<.001	0.11	0.003	0.10	0.071	156.0	156.3	156.5	0.464
Household wealth index [§]	0.17	<.001	0.27	0.007	0.07	0.532	0.34	0.210	0.91	0.132	-0.276	-0.025	-0.073	<.001
Survey [‡]		<.001		0.040		0.002		0.112		0.001				
2000	-0.42		-0.43		-0.40		-0.26		-1.24					
2005	0.01		0.30		0.02		0.25		-0.52					
2011	referent		referent		referent		referent		referent					

*p value for comparison the mean HAZ in each subgroup to the referent subgroup

†p value for variable's contribution to overall model

‡Categorical variable

§Continuous variable

Table 3. Linear regression model with HAZ as outcome which includes only children 6–23 months of age and only variables collected in all three DHS, applied to each of four livelihood zone categories, national

Variable	National (n=6,154; R ² =0.203)			Urban (n=966; R ² =0.315)			Agricultural (n=4,364; R ² =0.196)			Agro-pastoral (n=380; R ² =0.229)			Pastoral (n=346; R ² =0.206)			Comparison of survey results		
	β (beta) coeff-icent [†]	P value [†]		β (beta) coeff-icent [†]	P value [†]		β (beta) coeff-icent [†]	P value [†]		β (beta) coeff-icent [†]	P value [†]		β (beta) coeff-icent [†]	P value [†]		2000	2005	2011
Child's sex [‡]																		
Male	-0.41	<.001		-.32	0.032		-0.43	<.001		-0.96	<.001		0.33	0.144		51.1%	48.6%	50.8%
Female	referent			referent			referent			referent			referent			48.9%	51.4%	49.2%
Child's age (in months) [§]	-0.10	<.001		-0.11	<.001		-0.10	<.001		-0.04	0.033		-0.10	<.001		14.34	13.75	13.98
Child's estimated size at birth [‡]																		
Very large	0.61	<.001		1.45	0.001		.587	<.001		.032	0.998		1.002	0.026		4.7%	22.4%	17.6%
Larger than average	0.47			.05			.520			.003			.641			22.6%	9.2%	11.6%
Average	0.37			.46			.350			-.082			.929			36.2%	38.8%	39.2%
Smaller than average	0.12			-.19			.121			.005			.741			30.2%	6.7%	9.2%
Very small	referent			referent			referent			referent			referent			6.4%	22.9%	22.3%
Child's weight-for- height z-score [§]	-0.07	0.022		-0.02	0.720		-0.08	0.026		-0.02	0.879		-0.21	0.037		-0.92	-0.66	-0.73
Child drank non- human milk [‡]																		
No	-0.19	0.002		-0.30	0.044		-0.24	<.001		0.09	0.734		0.41	0.085		66.5%	60.6%	78.1%
Yes	referent			referent			referent			referent			referent			33.5%	39.4%	21.9%
Mother's height (in cm) [§]	0.05	<.001		0.06	<.001		0.05	<.001		0.06	<.001		0.04	0.093		156.6	156.7	156.4
Mother's BMI [§]	0.04	0.006		0.07	0.002		0.03	0.126		0.10	0.090		0.01	0.848		19.9	20.2	20.1

(Continues)

Table 3. (Continued)

Variable	National (n=6,154; R ² =0.203)		Urban (n=966; R ² =0.315)		Agricultural (n=4,364; R ² =0.196)		Agro-pastoral (n=380; R ² =0.229)		Pastoral (n=346; R ² =0.206)		Comparison of survey results		
	β (beta) coeff-icent [†]	P value [†]	β (beta) coeff-icent [†]	P value [†]	β (beta) coeff-icent [†]	P value [†]	β (beta) coeff-icent [†]	P value [†]	β (beta) coeff-icent [†]	P value [†]	2000	2005	2011
Mother uses contraception		0.014		0.851		0.037		0.033		0.210			<.001
No	-0.22		0.03		-0.25		-0.88		-0.34		93.5%	87.0%	75.6%
Yes	referent		referent		referent		referent		referent		6.5%	13.0%	24.4%
Mother's partner's occupation [‡]		0.015		0.570		0.085		0.041		0.345			<.001
None	0.68		.225		.602		1.746		.357		0.2%	1.2%	1.0%
Agriculture/ Unskilled	0.10		.23		.018		.025		-.408		85.9%	88.4%	80.1%
Service/Sales/ Prof	referent		referent		referent		referent		referent		13.9%	10.4%	18.9%
Sex of household head		0.005		0.333		0.002		0.468		0.863			0.831
Male	0.23		0.21		0.28		-0.25		0.10		88.2%	87.9%	87.4%
Female	referent		referent		referent		referent		referent		11.8%	12.1%	12.6%
Household wealth index [§]	0.28	<.001	0.33	<.001	0.30	<.001	0.68	0.127	-0.08	0.713	-.295	.000	-.064
Survey [‡]		<.001		0.151		<.001		0.215		<.001			<.001
2000	-0.56		-.26		-.616		-.520		-.268				
2005	-0.36		-.28		-.429		-.307		1.181				
2011	referent		referent		referent		referent		referent				

*p value for comparison the mean HAZ in each subgroup to the referent subgroup

†p value for variable's contribution to overall model

‡Categorical variable

§Continuous variable

beta coefficients indicated a comparable strength of association. On the other hand, household wealth showed a substantially weaker strength of association in agricultural households than in other livelihood groups.

Of the factors included in the final multivariate models for children less than 6 months of age, only estimated birth size and household wealth index show significant changes between the three surveys, but for both variables, no clear trend between the surveys is observed. Mother's height consistently increased since 2000, but the changes were not significant.

Multivariate and trend analyses – children 6–23 months of age

Table 3 presents the model results for children 6–23 months of age. The residuals for this model are normally distributed and show no association with predicted values of HAZ derived from the regression equation (results not shown). The overall regression explains 20.4% of the variation in HAZ ($R^2=0.204$), and significant predictors of HAZ include child characteristics (sex, age, birth order, estimated size at birth, WHZ), child feeding characteristics (child drank non-human milk in past 24 hours), maternal factors (height, BMI, partner's occupation, use of a modern form of contraception), and household factors (sex of household head, household wealth). HAZ was higher in girls than in boys, younger children, larger estimated birth sizes, lower WHZ, and greater mother's height. HAZ was greater in children with lower birth order, children who drank non-human milk, children whose mothers had a greater BMI, children whose mothers used contraception, children whose mothers' partner had no occupation, children in male-headed households, and children in wealthier households.

The livelihood models explained from 19.6 – 31.5% of HAZ's variability. Unlike in younger children, child age is statistically significantly associated with HAZ in all models. Estimated birth size is significantly associated with HAZ in all but the agro-pastoral models; however, there is no clear dose-response relationship in urban or pastoral areas (results not shown). Non-human milk consumption is only marginally associated with HAZ in urban areas and does not contribute to the model with statistical significance in agro-pastoral or

pastoral children. Mother's height was found to be a significant and positive predictor in all livelihoods zones except pastoral, whereas maternal BMI was only significantly associated with HAZ in urban areas. In urban populations, the average HAZ was very similar between children whose mothers used contraception and whose mothers did not. On the other hand, maternal use of contraception was significantly associated with HAZ in agricultural and agro-pastoral areas. Although the contribution to the model of mother's partner's occupation was only of marginal or insignificant relevance in all livelihood-specific models, children whose mother's partner had no occupation were still taller in all rural populations. The sex of the household head is only significant in agricultural areas. Household wealth index shows a significant and positive association with HAZ in urban and agricultural models, and although the beta coefficient is relatively high in agro-pastoral areas, indicating an association, the *p* value is not significant. This association is much weaker in pastoral areas.

There are substantial differences in the trends between 2000 and 2011 among these independent variables. The only consistent trend shown in the three surveys is mother's use of modern contraceptive methods, which increased from 6.5 in 2000 to 24.4% in 2011. Similar to children <6 months of age, the proportion of children 6–23 months of age with both very large and very small estimated birth size increased between 2000 and 2011, but no clear trend was apparent in other sub-groups. Other factors, such as average child's WHZ, proportion of children having consumed non-human milk in the past 24 hours, average BMI of mothers, and average household wealth index, increased from 2000 to 2005, and then decreased from 2005 to 2011.

Multivariate and trend analyses – children 24–59 months of age

Table 4 presents the model results for children 24–59 months of age. The overall regression explains 12.2% of the variation in HAZ ($R^2=0.122$), and the models' residuals are normally distributed and not associated with predicted values of HAZ (results not shown). Significant predictors of HAZ include child

Table 4. Linear regression model with HAZ as outcome which includes only children 24–59 months of age and only variables collected in all three DHS, applied to each of four livelihood zone categories, national

Variable	National (n = 9,022; R ² = 0.122)		Urban (n = 1,229; R ² = 0.243)		Agricultural (n = 6,587; R ² = 0.107)		Agro-pastoral (n = 554; R ² = 0.139)		Pastoral (n = 504; R ² = 0.301)		Comparison of survey results			
	β coeff- icient [†]	P value [‡]	β coeff- icient [†]	P value [‡]	β coeff- icient [†]	P value [‡]	β coeff- icient [†]	P value [‡]	β coeff- icient [†]	P value [‡]	2000	2005	2011	p-value
Child's birth order [§]	-0.08	0.001	-0.04	0.522	-0.08	0.001	-0.02	0.763	-0.15	0.040	4.19	4.31	4.02	0.007
Child's estimated size at birth [‡]		<.001		0.006		<.001		0.738		0.002				<.001
Very large	.256		.449		.253		.418		.554		5.5%	23.1%	19.8%	
Larger than average	.218		.799		.183		.581		.015		26.7%	11.2%	12.8%	
Average	.192		.532		.178		.271		.137		36.7%	40.1%	39.6%	
Smaller than average	-.031		.442		-.062		.594		.025		25.8%	8.2%	8.5%	
Very small	referent		referent		referent		referent		referent		5.4%	17.5%	19.3%	
Child's weight-for- height z-score [§]	-0.17	<.001	-0.16	0.023	-0.17	<.001	-0.13	0.221	-0.33	0.001	-.58	-.40	-.44	<.001
Child had diarrhea past 2 weeks [‡]		<.001		0.130		<.001		0.029		0.986				<.001
No	0.27		0.29		0.25		0.52		0.01		81.2%	86.4%	90.4%	
Yes	referent		referent		referent		referent		referent		18.8%	13.6%	9.6%	
Child had fever past 2 wks [‡]		0.006		0.251		0.001		0.613		0.683				<.001
No	0.15		-0.16		0.21		-0.08		0.08		74.6%	83.6%	85.5%	
Yes	referent		referent		referent		referent		referent		25.4%	16.4%	14.5%	
Child drank non- human milk [‡]		<.001		0.062		<.001		0.093		0.182				<.001
No	-0.18		-0.22		-0.22		0.22		0.27		72.9%	62.6%	81.6%	
Yes	referent		referent		referent		referent		referent		27.1%	37.4%	18.4%	
Mother's height (in cm) [§]	0.05	<.001	0.06	<.001	0.04	<.001	0.04	<.001	0.08	<.001	156.6	157.2	156.8	.086
Mother's BMI [§]	0.05	<.001	0.04	0.006	0.05	<.001	0.01	0.727	0.13	0.007	20.1	20.4	20.4	.529

(Continues)

(Continues)

Table 4. (Continued)

Variable	National (n = 9,022; R ² = 0.122)		Urban (n = 1,229; R ² = 0.243)		Agricultural (n = 6,587; R ² = 0.107)		Agro-pastoral (n = 554; R ² = 0.139)		Pastoral (n = 504; R ² = 0.301)		Comparison of survey results		
	β coeff- icient [†]	P value [†]	β coeff- icient [†]	P value [†]	β coeff- icient [†]	P value [†]	β coeff- icient [†]	P value [†]	β coeff- icient [†]	P value [†]	2000	2005	2011
Mother's educational level [‡]		0.001		0.020		0.024		0.011		0.097			
None	-406		-413		-434		-1.152		-.941		82.4%	78.9%	70.9%
Primary	-.345		-.151		-.390		-1.089		-1.563		12.6%	17.0%	26.1%
Secondary	referent		referent		referent		referent		referent		5.0%	4.2%	3.0%
Number of mother's living children [§]	0.08	0.003	0.05	0.491	0.09	0.002	-0.06	0.404	0.20	0.050	3.93	4.27	4.01
Number of children <5 yrs in household [§]	0.07	0.071	-0.09	0.278	0.09	0.056	-0.06	0.442	0.41	0.006	1.81	1.89	1.83
Age of household head [§]	0.01	<.001	0.01	0.130	0.01	<.001	0.01	0.766	0.01	0.552	39.7	39.2	38.2
Dependency ratio [§]	-0.10	<.001	0.08	0.303	-0.13	<.001	0.13	0.053	-0.18	0.217	1.49	1.69	1.66
Household wealth index [§]	0.20	<.001	0.22	<.001	0.13	0.062	0.49	0.025	0.79	0.001	-.277	-.024	-.099
Percent households practicing open defecation [§]		0.028		0.929		0.088		0.002		<.001			
<=10%	-132		.205		-.326		.163		1.299		2.5%	8.4%	10.5%
11-26%	-234		.058		-.175		-.471		-.595		4.6%	9.3%	16.8%
27-43%	-.055		.095		-.021		-.346		-.738		3.2%	9.5%	22.2%
44-63%	-.082		.195		-.085		-.126		.063		4.3%	9.8%	19.2%
64-81%	-.234		.053		-.211		-.416		-.267		8.0%	10.6%	17.1%
82-92%	-.242		.030		-.217		-.345		-.664		9.5%	15.0%	6.8%
93-99%	-.184		.205		-.166		.533		-.897		15.9%	13.1%	2.1%
100%	referent		referent		referent		referent		referent		52.0%	24.3%	5.2%
Survey [§]		<.001		<.001		<.001		<.001		0.764			
2000	-.535		-.624		-.535		-.785		.036				
2005	-.287		-.288		-.289		-.239		.171				
2011	referent		referent		referent		referent		referent				

*p value for comparison the mean HAZ in each subgroup to the referent subgroup

[†]p value for variable's contribution to overall model[‡]Categorical variable[§]Continuous variable

characteristics (birth order, estimated size at birth, WHZ), recent disease (diarrhea and/or fever in past 2 weeks), feeding characteristics (child drank non-human milk in past 24 hours), maternal factors (height, BMI, education), household factors (mother's number of living children, number of children <5 year old in the household, age of household head, dependency ratio, household wealth), and community factors (percent of households in cluster practicing open defecation). Estimated size at birth again shows a dose-response relationship with HAZ with smaller children having a lower HAZ, and mean HAZ is higher in children without recent fever and diarrhea (results not shown). Children consuming non-human milk in the past 24 hours have higher HAZ. Mother's height, BMI, and education are positively associated with HAZ, indicating that taller, better-nourished, and more-educated mothers have taller children; however, most of the difference in HAZ by mother's education appears between mother with primary education and those with more advance education. There is relatively little difference in HAZ between mothers with no education and with only primary education. Among household composition factors, only dependency ratio shows a negative association with HAZ, suggesting that child's nutrition is adversely affected in households with a higher proportion of dependants. Household wealth is positively associated with HAZ, indicating that as household wealth increases, stunting decreases. Although significant associations were found, no discernible pattern between the proportion of households in each cluster openly defecating and HAZ is observed, and category-specific mean HAZ ranges from -2.42 to -2.18. Survey year shows that mean HAZ increases steadily over time.

The livelihood-specific models explain between 10.7 and 30.1% of the variability in HAZ, with the best fit in the pastoral model. Estimated size at birth and WHZ is significantly associated with HAZ in all livelihood zones except agro-pastoral, yet there is no clear trend in the mean HAZ by for each sub-group of perceived birth size. WHZ is negatively associated with HAZ. Recent morbidity are significantly associated with HAZ in agricultural (both fever and diarrhea) and agro-pastoral (diarrhea only) models; the mean HAZ for children with recent illness in these areas is significantly lower than in non-ill children. Recent-

consumption of non-human milk in the past 24 hours is significantly associated with HAZ in agricultural areas. Mother's height and BMI are significant and positive predictors of HAZ in nearly all livelihood models. Child HAZ is higher in more educated mothers in all models except pastoral, where the association is not significant. HAZ increases as household wealth increases; however, this increase in HAZ with household wealth is lower and not statistically significant in agricultural households. At the community level, the practice of open defecation is significantly associated with HAZ in agro-pastoral and pastoral communities; however, there is no clear dose-response relationship between sub-groups with different level of open defecation. Lastly, survey year significantly associated with all models except the pastoral model; in models where a significant association is found, mean HAZ increases steadily over time.

Amongst the various explanatory factors associated with HAZ, there is a significant and consistent trend in recent diarrhea, fever, and mother's education. For the overall model, there is also a clear trend in the change in open defecation. From 2000 to 2011 the 2-week cumulative prevalence of diarrhea decreased from 18.8 to 9.6%, and the 2-week cumulative prevalence of fever declined from 25.4 to 14.5% in the same time period. Mother's education consistently improved, with the proportion of women with a primary education increasing from 12.6% in 2000 to 26.1% in 2011. Open defecation at the community level decreased dramatically; in 2000 52% of children 24–59 months of age lived in communities where 100% of households practiced open defecation, whereas in 2011 only 5.2% of these children were in communities where open defecation was exclusively practiced.

Discussion

Factors associated with HAZ in each age group

Children less than 6 months of age have not typically been included in assessments of nutritional status because they were generally considered protected from malnutrition by breastfeeding. Widespread use of the new WHO Child Growth Standard has refuted this assumption and demonstrated that children in this age

group do indeed have both acute and chronic malnutrition (de Onis *et al.* 2006). Our analysis adds to the relatively sparse data examining factors related to stunting in this age group. Perhaps the most striking conclusion is that relatively few factors are associated with HAZ. In this age group, HAZ is not statistically significantly related to variables measuring child feeding, child morbidity, perinatal care, mother's health (except height), parent characteristics, household characteristics (except wealth index), or environmental sanitation and hygiene. Specifically, regarding perinatal variables, which might be expected to play a role in stunting, our analysis fails to demonstrate a statistically significant association between HAZ and birth order, mother's smoking, or measures of ante-natal care. Feeding variables, including exclusive breastfeeding, are not statistically significantly related to HAZ. This finding is consistent with other published studies (Kramer & Kakuma 2012; Vesel *et al.* 2010). In general, this analysis reveals few direct points for intervention to prevent future stunting in this age group. Nonetheless, the strong association between HAZ and birth size and maternal height – slowly-changing indicators of women's nutritional status at the population level – may indicate that maternal and ante-natal interventions could increase fetal growth and thus lead to higher birth weight and greater linear growth in the first half of infancy and perhaps later in a child's life.

Although more factors are associated with linear growth in children 6–23 months of age, the age of maximum growth faltering in Ethiopia and other developing countries, the factors that are modifiable by public health interventions are consumption of non-human milk, mother's use of modern contraception, and mother's height and BMI. In Ethiopia, milk consumption by young children, particularly during the lean season, has been shown to prevent stunting and wasting (Sadler *et al.* 2012). The use of modern contraceptives has also been associated with stunting, perhaps by increasing the space between births and by increasing overall knowledge of maternal and child health issues (Finlay 2012). In Ethiopia, because the Health Extension Program is the major provider of contraceptive services (Medhanyie *et al.* 2012), the use of contraception may reflect access to and use of this program which provides other health and nutrition services which may

have played a role in ameliorating stunting (Wirth *et al.* 2016). Thus, the apparent association between contraceptive use and HAZ may be due to confounding by participation in these other parts of the Health Extension Program. Maternal height and BMI have also been associated with stunting in previous studies in Ethiopia (Gibson *et al.* 2009; Fentaw *et al.* 2013), illustrating that maternal height and nutrition status are closely associated with child growth in Ethiopia. Many other direct measures of child feeding behaviors, however, did not exhibit a statistically significant association with HAZ, including ever breastfeeding, early initiation of breastfeeding, drinking from a bottle with a nipple, dietary frequency, dietary adequacy, eating vitamin A rich foods, and consumption of iodized salt. Compared to younger children less than 6 months of age, more household factors are associated with HAZ, including mother's partner's educational level, sex of the household head, and household wealth.

In children 24–59 months of age, the list of variables significantly associated with HAZ is even longer than in younger children. Like younger children, estimated size at birth, child's WHZ, and mother's height and BMI remain significantly associated with HAZ. On the other hand, unlike in younger children, various measures of child morbidity and household composition are associated with HAZ. Diarrhea and respiratory infections result in stunting, as shown by prospective studies in other developing countries (Adair & Guilkey 1997; Kossmann *et al.* 2000; Checkley *et al.* 2008), but we found only one other published study from Ethiopia reporting a significant relationship between recent diarrhea and child growth (Teshome *et al.* 2009). In addition, mother's educational level becomes associated with HAZ in this age group. The association between mother's education and child's health and nutritional status is well documented in other countries (Adekanmbi *et al.* 2013; Muhangi *et al.* 2013). Because the direct effect of diarrheal disease on HAZ is accounted for in the linear regression model, the decline in the prevalence of open defecation has an independent effect on HAZ. Open defecation at the community level has recently been identified as a potential cause of child stunting (Spears 2013), and its significance

only in children 24–59 months, may be due to the fact that these children are more mobile, and thus have more “contact” with the environment outside the home than younger children.

Overall, only a few variables are associated with HAZ in all age groups; these include child’s WHZ, child’s estimated size at birth, mother’s height, and household wealth index. Most of these variables are, however, not *modifiable* by short-term public health interventions. Modifiable variables may be age-specific. Thus, program planners and managers should be sensitive to the fact that interventions may have effects on some age groups and not others.

Factors associated with HAZ in each livelihood zone

Our analysis finds that the factors associated with child growth are quite consistent between urban and rural areas. There are few factors that were significant only in either urban or rural areas but not both. More frequently, there are differences in the association between HAZ and a given factor in the three rural livelihood zones, which is likely due to the diversity of culture and livelihoods in rural areas of Ethiopia. For example, recent consumption of milk in children 6–23 months of age is associated with higher HAZ in urban and agricultural areas, but not agro-pastoral or pastoral. This may be due to the fact that milk is more frequently consumed by pastoral communities than agrarian communities, and milk consumption in pastoral areas is constant except during dry seasons and droughts (Sadler *et al.* 2012). Mother’s use of modern contraception is significantly associated with HAZ in agricultural and agro-pastoral communities, but not urban or pastoral areas. If use of modern contraception is considered a proxy of health care coverage, the lack of variability in health care coverage in these subpopulations (nearly universal in urban areas and nearly inaccessible in nomadic populations) may preclude measurement of associations with this variable. Similarly, the statistically significant association between measures of child morbidity and HAZ seen in agricultural areas, but not in urban or pastoral areas, may reflect universal access or lack of access in urban and pastoral areas. In agricultural areas, there may be great

variability in access so that more effective and timely treatment for child illness somewhat ameliorates the nutrition effects of such illness.

Other factors showed consistent relationships in the livelihood models. In particular, maternal factors, e.g. height, BMI and education, are consistently associated with improvement in older child growth irrespective of livelihood zone.

Trends in factors and contribution to stunting reduction

Although the multivariate analysis described above identified several variables which were statistically significantly associated with HAZ in one or more age groups, whether or not a given variable contributed to the decline in the prevalence of stunting seen in Ethiopia between 2000 and 2011 depends on the trend in that variable. Even if a factor is associated with HAZ, if the level of that factor did not substantially change during this time period, it probably did not contribute. In fact, many of the factors remaining in the final age-specific and livelihood zone-specific multivariate models did not substantially change between 2000 and 2011.

Of course, certain demographic variables, such as age and sex distribution in children and sex of the household head, can be expected to be relatively constant during this short time period. Indeed, these variables did not change with statistical significance in Ethiopia. Other demographic variables, such as birth order, mother’s educational level, number of mother’s living children, and household wealth, did change and could therefore be contributors to the decline in stunting prevalence. Regarding maternal education, Ethiopia’s elimination of school fees for primary education in 2002 and the increased public funding for education have expanded the access to primary education to girls throughout Ethiopia by reducing households’ opportunity costs of sending girls to school (Oumer 2009), and thus may have contributed to the reduction in stunting observed. Some behavioral factors such as mother’s use of contraceptives and child’s consumption of milk were both associated with HAZ and changed in the expected direction during this time period. Maternal nutritional indicators, such

as mother's height and BMI, were either unassociated with HAZ or did not change during this time period in many age- and livelihood-specific groups. Interestingly, the only potentially contributory nutritional or dietary variable which might respond in the short-term to nutrition programming is child's consumption of milk. On the other hand, indicators of child morbidity were both associated with HAZ and changed, at least in the oldest age group. Possible targets of more general health intervention, such as birth weight and child morbidity may also have an effect on stunting prevalence.

Interventions to address stunting in Ethiopia

The failure of our analysis to identify various dietary factors as potentially contributing to the decline of stunting in Ethiopia may be due to the inexact nature of the indicator measurements or other reasons. A similar lack of association between complementary feeding indicators and stunting has been found in several countries in Africa and elsewhere (Onyango *et al.* 2014). Nonetheless, further diversification of complementary feeding diets in children older than 6 months of age may contribute to additional reductions in stunting prevalence as a relationship between the quality of complementary feeding and stunting has been observed in multiple countries (Ruel & Menon 2002; Arimond & Ruel 2004). The low proportion of children in the 2011 DHS (3.7%) with a minimally acceptable diet highlights the need for specific interventions to improve complementary feeding. In addition, our analysis found that though consuming non-human milk has a protective effect in children 6–23 months old, there is a decline since 2000 in the proportion of children consuming milk. Further research is warranted to determine which other dietary programs targeted to which age groups might be effective. And finally, encouraging girls' education to produce better educated mothers can be expected to further reduce stunting.

Programs improving child health, especially those preventing and/or treating diarrhea and fever, should result in further decline in the prevalence of stunting. Although the prevalence of open defecation has substantially declined in Ethiopia since 2000, the majority of latrines used in Ethiopia are pit latrines without slabs, which are classified by as *unimproved* by WHO

& UNICEF (2015). Thus, increased coverage of *improved* sanitation facilities may result in additional reductions in stunting prevalence by further preventing diarrhea and environmental enteropathy. In addition, programs that improve mother's health, nutrition, and education status may reduce stunting by improving fetal growth and care giving practices during infancy and early childhood.

Limitations

Although DHS data were the only data available in Ethiopia to undertake this analysis, DHS data have several limitations and thus can provide neither a complete picture of factors contributing to stunting in Ethiopia nor all the factors responsible for its reduction since 2000.

Notably, the three DHS were done in somewhat different seasons, and thus, any outcomes showing seasonal variation may show differences among the three surveys solely because the measurement was done at different times of the year. In addition, DHS data does not include direct measures of household food security or children's dietary intake which are major putative risk factors for stunting. Although the household wealth index and children's dietary diversity may serve as proxies for food security and dietary intake, respectively, they are at best indirect measures.

DHS data also contain no assessment of participation of selected households in any of the many nutrition and health programs existing in Ethiopia, although some factors (e.g. use of contraception) can potentially serve as proxies for primary health care coverage. In general, the effect of these potentially important programs cannot be measured in our analysis. Because such nutrition and health programs may mitigate the effect of possible risk factors included in our analysis, we may be underestimating the contribution of such risk factors to stunting in the absence of interventions.

Similar to other studies from Ethiopia (Gibson *et al.* 2009; Assefa *et al.* 2012), our analysis found consistent associations between household wealth index and child HAZ. Although household wealth index is routinely calculated, significant findings are difficult to ascribe to any specific household characteristic because it is a

composite measure. To illustrate, household wealth index includes a household's durable goods (e.g. radio, television, watches, tools), dwelling construction (e.g. material used for floors, walls, and roof), household sanitation (e.g. latrine type), and ownership of live-stock; and all of these factors have the potential to influence child growth. However, when included separately in the age-specific models, none of the sub-factors were significant at the household level.

Regarding data quality, some heaping of the decimal in height measurements in the 2000 and 2005 DHS were observed. There was no heaping of age on whole years, but there is an uneven distribution of age in children less than 5 years of age. Standard recommendations state that a standard deviation of greater than 1.3 for HAZ reflects excessive random variation in either height measurements or age estimates. The standard deviation of HAZ in the three DHS greatly exceeds this threshold for data quality; however, this recommendation is based on the use of the old NCHS/CDC/WHO reference population. There is evidence that standard deviations for HAZ greater than 1.3 are common in DHS in other countries and may be normal when using the WHO Child Growth Standard (Mei & Grummer-Strawn 2007). Regardless, the HAZ values were normally distributed in each survey without substantial skewness or kurtosis. If the standard deviation actually reflects imprecise data, it is most likely due to poor age estimates in this largely calendar-illiterate population.

Due to the limitations of DHS, policy makers and program managers in Ethiopia and other countries should use DHS in tandem with evidence from other studies, and should design independent studies to inform key programmatic questions. To address the limitations of this analysis, we recommend that nutrition researchers in Ethiopia examine the determinants of stunting using different study designs. For example, longitudinal cohort studies that examine children at multiple times from birth to five years of age and examine factors often absent from DHS surveys (e.g. household food security, dietary intake, participation in nutrition and health programs, micronutrient and inflammation status) can identify factors directly associated with and preceding growth faltering. Moreover, the greater control inherent in

collecting data as part of such a study would reduce random measurement error in key variables, such as feeding indicators.

Conclusion

Despite a large reduction in the prevalence of stunting in Ethiopia since 2000, the prevalence of stunting remains unacceptably high. Our analysis finds that factors associated with child growth in Ethiopia vary considerably by age and livelihood zone, with relatively few modifiable factors in children < 6 months of age. In older children 6–59 months old, more factors were associated with HAZ, including some amenable to modification by intervention: recent illness, maternal health and education, and community-level sanitation. Factors that are associated with the decline in the stunting prevalence since 2000 include decreases in the prevalence recent illness and community-level open defecation and improvements in maternal height, BMI, and education. To further accelerate and sustain the reduction in stunting observed in Ethiopia, education and health programs targeted to women should be continued, along with programs to reduce child illness and address community sanitation.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

BW, JPW, and FR conceptualized the study and analysis approach. BW conducted all data analyses. BW, JPW, and FR drafted the first version of the manuscript and all authors thoroughly reviewed to subsequent versions, including the version finally submitted.

Disclaimer

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