

Elucidating the sustained decline in under-three child linear growth faltering in Nepal, 1996–2016

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Abstract

Childhood linear growth faltering remains a major public health concern in Nepal. Nevertheless, over the past 20 years, Nepal sustained one of the most rapid reductions in the prevalence of stunting worldwide. First, our study analysed the trends in height-for-age z-score (HAZ), stunting prevalence, and available nutrition-sensitive and nutrition-specific determinants of linear growth faltering in under-three children across Nepal's Family Health Survey 1996 and Nepal's Demographic and Health Surveys 2001, 2006, 2011, and 2016. Second, we constructed pooled multivariable linear regression models and decomposed the contributions of our time-variant determinants on the predicted changes in HAZ and stunting over the past two decades. Our findings indicate substantial improvements in HAZ (38.5%) and reductions in stunting (−42.6%) and severe stunting prevalence (−63.9%) in Nepalese children aged 0–35 months. We also report that the increment in HAZ, across the 1996–2016 period, was significantly associated (confounder-adjusted $p < .05$) with household asset index, maternal and paternal years of education, maternal body mass index and height, basic child vaccinations, preceding birth interval, childbirth in a medical facility, and prenatal doctor visits. Furthermore, our quantitative decomposition of HAZ identified advances in utilisation of health care and related services (31.7% of predicted change), household wealth accumulation (25%), parental education (21.7%), and maternal nutrition (8.3%) as key drivers of the long-term and sustained progress against child linear growth deficits. Our research reiterates the multifactorial nature of chronic child undernutrition and the need for coherent multisectoral nutrition-sensitive and nutrition-specific strategies at national scale to further improve linear growth in Nepal. [Correction added on 6 November 2020, after first online publication: in abstract, the citation year in the fourth sentence has been changed from '2001' to '2011'.]

KEYWORDS

chronic malnutrition, Demographic and Health Surveys, infant and child nutrition, linear growth, Nepal, statistical decompositions, stunting

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1 | INTRODUCTION

At present, 149 million under-five children are stunted worldwide, and two out of five stunted children reside in South Asia (UNICEF, WHO [World Health Organization] & World Bank Group, 2019). Chronic malnutrition, linear growth faltering in particular, contributes between 15% and 17% of all deaths in children worldwide and approximately 400,000 deaths in South Asia alone (Black et al., 2013). Furthermore, inadequate height for age has adverse effects on children, including an increased risk for infectious diseases, cognitive and mental development deficits, poorer school performance, lower adult wages and productivity, and a greater risk of nutrition-related non-communicable diseases later in life (Black et al., 2008; Victora et al., 2008). Although child linear growth faltering has progressively declined, in the 1990s, South Asia suffered disproportionately higher rates and poorer reduction of chronic malnutrition relative to the region's economic development and the progress made in sub-Saharan Africa (Drèze & Deaton, 2009; Headey, Chiu, & Kadiyala, 2012; Nubé, 2009). To illustrate, Demographic and Health Surveys (DHS) conducted during the mid-1990s indicated that over half of under-five children in South Asia were stunted (Headey, Hoddinott, & Park, 2016). This phenomenon, coined as the Asian Enigma, led to extensive research exploring the potential explanations for the lack of headway against child linear growth faltering in the region (see *Introduction* in Headey et al., 2016). Nevertheless, over the past 20 years, several South Asian countries have made unprecedented improvements on child linear growth outcomes (Headey et al., 2016; Headey, Hoddinott, & Park, 2017). Hence, more recent research has laid attention on elucidating the rapid and sustained reduction of child linear growth faltering in South Asia over time. To illustrate, Headey and Hoddinott (2015) reported that Nepal, amidst socioeconomic and political instability, achieved one of the fastest declines in the prevalence of stunted under-five children (–29%) in the world from 2001 to 2011. The improvement was primarily attributed to national-level policy decisions made by the Government of Nepal (GoN), including increased public investments in health care and education and community-led health and sanitation campaigns (Headey & Hoddinott, 2015). Furthermore, Nepal's Ministry of Health and Population reported that the under-five child stunting trend continued to decline after 2011, although in 2016 chronic undernutrition remained a major public health concern, with 36% of Nepalese children under-five stunted and 12% severely stunted (Ministry of Health and Population, New ERA & ICF International, 2017).

In recognition of stunting as an important nutritional outcome in itself and a marker of multiple short- and long-term adverse outcomes (Dewey & Begum, 2011; Hoddinott et al., 2013), global development attention has been directed towards reducing the high burden of child linear growth deficits in low- and middle-income countries (LMIC; Leroy & Frongillo, 2019). To illustrate, the United Nations Decade of Action on Nutrition (2016–2025) and sustainable development goals comprise specific targets to reduce malnutrition, including a 40% reduction in the number of stunted children under-five by 2025. UNICEF also set a South Asia target of 10 million fewer stunted children by 2021. Furthermore, over the last decade, the GoN has shown strong and

Key messages

- Nepal achieved rapid and sustained progress on height-for-age z-score (38.5%) and stunting (–42.6%) and severe stunting prevalence (–63.9%) in under-three children over the 1996–2016 period.
- Four broad drivers accounted for much of the observed change in chronic child undernutrition over time: utilisation of health care and related services, household wealth, parental education, and maternal nutrition.
- Monitoring and evaluation of multisectoral nutrition policies and integrated programmes ought to cover a spectrum of distal socioeconomic factors, rather than a narrower focus on proximal nutrition-specific indicators only.

unprecedented political commitment and action to tackle chronic childhood undernutrition. This included an early riser membership of the global Scaling Up Nutrition movement in 2011, implementation of the Multi Sector Nutrition Plan (MSNP) I (2013–2017) and Food and Nutrition Security Plan (2013–2023), increased nutrition-sensitive and nutrition-specific investments, and endorsing and approving the MSNP II (2018–2022) to help achieve global and national malnutrition targets (Ministry of Health and Population Nepal, 2017).

In this research paper, we aimed to address two interrelated but distinct questions: (a) which nutrition-sensitive and nutrition-specific determinants best explain long-term variations in child linear growth outcomes among under-three children in Nepal? and (b) which of these determinants best predict the observed change in child linear growth outcomes over the past 20 years? For that purpose, we applied a regression-decomposition analysis, built on the quantitative, dynamic, and comparative approaches described in Headey et al. (2015, 2016, 2017). Our study extends previous literature on the long-term drivers of chronic child malnutrition in Nepal (Cunningham, Headey, Singh, Karmacharya, & Rana, 2017; Headey & Hoddinott, 2015) by assessing HAZ, stunting, and severe stunting trends in children aged 0–35 months over the most comprehensive time frame available, using five national surveys between 1996 and 2016. Furthermore, our statistical decompositions considered a more exhaustive list of available nutrition-sensitive and nutrition-specific determinants of child linear growth faltering, including multiple indicators of age-appropriate child feeding practices (Aguayo & Menon, 2016; Headey et al., 2017; Menon, Headey, Avula, & Nguyen, 2018). Our timely revision of evidence on the drivers of country-level nutritional change is relevant for evidence-based decision-making and monitoring and evaluation of multidimensional policies and integrated programmes, such as the MSNP II (2018–2022) and Suaahara II (2016–2021). [Correction added on 6 November 2020, after first online publication: the reference citation has been amended to 'Headey et al. (2015, 2016, 2017)'.]

2 | DATA AND METHODS

This study is reported according to the STROBE checklist for cross-sectional studies (von Elm et al., 2007).

2.1 | Data sources

To examine changes in child linear growth outcomes over time, we analysed Nepal's Family Health Survey (NFHS) 1996 ($n = 3,703$) and four rounds of Nepal's Demographic and Health Surveys (NDHS) 2001 ($n = 3,729$), 2006 ($n = 3,003$), 2011 ($n = 1,424$), and 2016 ($n = 1,403$). For consistency across all five survey rounds, our analysis was restricted to individual-level recode data from children aged 0–35 months (Corsi, Neuman, Finlay, & Subramanian, 2012). This age range covers the crucial postnatal window in which most population growth faltering occurs in LMIC (Victora et al., 2010). Furthermore, NFHS and NDHS multicluster cross-sectional surveys of ever-married women of reproductive age (15–49 years) are well suited to our purpose, insofar as they are high quality, nationally representative, and standardised across rounds in their coverage of a wide, albeit nonexhaustive, range of hypothesised nutrition-sensitive and nutrition-specific drivers of child linear growth faltering and anthropometric outcomes. Further details of these data sets are reported in Angdembe, Dulal, Bhattarai, and Karn (2019), and country-specific surveys are found in ICF International (2019).

2.2 | Outcomes

Roth et al. (2017) recently reported child linear growth faltering as a whole-population condition, thus affecting the entire height-for-age z-score (HAZ) distribution. Therefore, our research paper focused on HAZ, measured against the median of the WHO, 2006 Child Growth Standard (WHO, 2006; WHO & UNICEF, 2009), as the main dependent variable. In addition, due to the large pooled sample size ($n = 10,880$), we analysed the prevalence of stunting ($\text{HAZ} \leq 2 \text{ SD}$) and severe stunting ($\text{HAZ} \leq 3 \text{ SD}$). At present, stunting is regarded as the standard metric to monitor commitments and progress towards global (and national) chronic child undernutrition targets (de Onis et al., 2013; Devkota, Adhikari, & Upreti, 2016).

2.3 | Independent variables

Our time-variant independent variables at child-, parental-, and household-level were selected based on the Black et al. (2013) framework and a review of previous regression-decomposition analyses of HAZ (Cunningham, Headey, et al., 2017; Headey et al., 2015, 2016, 2017; Headey & Hoddinott, 2015; Menon et al., 2018). These covariates, representing nutrition-sensitive and nutrition-specific domains hypothesised to affect child linear growth outcomes over time, are straightforward inclusions in nutrition models (Table 1). The

TABLE 1 Variable definitions

Short name	Definition
HAZ	Height-for-age z-score (HAZ) measured against World Health Organization 2006 Child Growth Standards (WHO, 2006)
Stunting (%)	Percentage of children with $\text{HAZ} \leq 2 \text{ SD}$
Severe stunting (%)	Percentage of children with $\text{HAZ} \leq 3 \text{ SD}$
Asset index (1–10)	Five-component index
Maternal education (years)	Mother's years of education
Paternal education (years)	Father's years of education
Prenatal doctor visit (0/1)	Dummy = 1 if mother received a prenatal visit from a doctor
4 ⁺ ANC visits (0/1)	Dummy = 1 if mother received four or more antenatal care (ANC) visits
Iron during pregnancy (0/1)	Dummy = 1 if mother received iron supplements during pregnancy
Born in medical facility (0/1)	Dummy = 1 if child was born in hospital or other medical facility
Maternal BMI (kg/m^2)	Mother's body mass index
Maternal height (0/1)	Dummy = 1 if mother's height $\geq 145 \text{ cm}$
All vaccinations (0/1)	Dummy = 1 if child received BCG; polio (two shots); DPT (three shots); and MCV between 1996 and 2011 and/or pentavalent vaccination (three shots) in 2016
Birth order (rank)	Order a child is born in the family
Preceding birth interval (years)	Interval between birth of present child and any previous child
Open defecation (0/1)	Dummy = 1 if household does not have access to a latrine or toilet
Water tube well (0/1)	Dummy = 1 if household drinking water was sourced from tube well
Water source-piped (0/1)	Dummy = 1 if household drinking water was sourced from pipes
Women's decision-making (0/1)	Dummy = 1 if mother alone decides how her earnings are spent
Breastfeeding duration (months)	Months child is breastfed
Early initiation of breastfeeding (0/1)	Dummy = 1 if child was put to the breast within 1 hr of birth
Ever breastfed (0/1)	Dummy = 1 if child was ever breastfed
Bottle-feeding (0/1)	Dummy = 1 if child was fed with a bottle the previous day

Source: Authors' construction.

Abbreviations: BCG, Bacillus Calmette-Guerin vaccine against tuberculosis; DPT, diphtheria–pertussis–tetanus vaccine; MCV, measles antigen-containing vaccine.

strengths and weaknesses of various indicators are discussed later. Nevertheless, we do note: Following Filmer and Pritchett (2001), we used a DHS asset index to proxy for household wealth. These and other authors have shown that such DHS asset indices are fair proxies

for household socioeconomic status in terms of sharing strong correlations with other welfare indicators, including child linear growth outcomes (Headey & Hoddinott, 2015). To construct a common household asset index across all five data rounds, we conducted a pooled principal components analysis using five consistently measured durables. These five indicators and their respective factor loadings were bicycle ownership (0.31), television ownership (0.58), radio ownership (0.12), non-natural flooring material (0.51), and household access to electricity (0.55). After applying these loading weights, we rescaled the household asset index to vary between a minimum score of 1 and a maximum score of 10.

In addition, we adopted a flexible specification of time-invariant control variables to adjust the associations between time-variant independent variables and child linear growth outcomes, including month-specific child age dummy variables (capturing the progressive growth-faltering process that chronically malnourished populations undergo until around 24 months of age; Victora et al., 2010), religion and ethnicity variables, regional and agroecological zone variables, maternal age (in five-year intervals), child sex, stratum, and NFHS and NDHS survey round variables.

2.4 | Statistical analysis

Data management and statistical analysis were conducted using Stata version 15.1 (StataCorp, 2017). The weighted prevalence and average values of child linear growth outcomes and time-variant independent variables in each survey round were calculated considering the DHS sampling weight factor using the `svyset` command. Our analysis excluded all extreme HAZ values beyond the range of ± 6 SD from the median. We followed a two-step regression-decomposition approach to evaluate the important drivers of the change in child linear growth faltering from 1996 to 2016. First, to identify the key nutrition-sensitive and nutrition-specific determinants of child linear growth outcomes, we fitted multivariable ordinary least squares (OLS) regression models for the continuous HAZ outcome and multivariable linear probability models with a robust variance estimator (LPM) for the binary stunting outcomes on pooled data from all available survey rounds. The use of LPM for binary outcomes is well established in econometrics and allows for a straightforward interpretation of the average marginal effect of an explanatory variable, expressed as a probability difference using percentage points (p.p.; Hellevik, 2009; Wooldridge, 2002). The functional form (linearity assumption) of the relationships between HAZ and the time-variant continuous variables were examined using kernel-weighted local polynomial smoothing graphs.

Our multivariable regression models are represented in Equation (1) below, assessing the associations between linear growth outcomes (N) for a child i at time t and vectors of time-variant nutrition-sensitive and nutrition-specific determinants (X), vectors of mainly time-invariant control variables (μ_i), trend effects represented by a vector of year dummy variables (T), and a standard error term ($\varepsilon_{i,t}$).

$$N_{i,t} = \beta X_{i,k} + \mu_i + T + \varepsilon_{i,t} \quad (1)$$

In Equation (1), the vectors of coefficients (β) on X constitute the set of parameters of principal interest, which are used to answer the first of our two questions about the determinants of child linear growth faltering, that is, which nutrition-sensitive and nutrition-specific determinants best explain variations in child linear growth outcomes among children aged 0–35 months in Nepal from 1996 to 2016?

Second, we used the estimated parameters from Equation (1) to conduct a simple statistical decomposition at means described in Equation (2) below (under the assumption that the β coefficients are time invariant and the error term has a mean of zero). For our analysis, we selected the earliest NFHS 1996 round ($t = 1$) and the most recent NDHS 2016 round ($t = k$). To evaluate the contribution of important nutrition-sensitive and nutrition-specific determinants on the observed trends in child linear growth outcomes, our analysis entailed multiplying the β coefficient from Equation (1) by the change in the means of each explanatory variable across the 1996–2016 period. This gives the predicted change in child linear growth outcomes due to the change in an explanatory variable over the past 20 years and thus shows the estimated contribution of each time-variant variable to changes in child linear growth outcomes.

$$\Delta \bar{N}_{i,t} = \beta (\bar{X}_{t=k} - \bar{X}_{t=1}) \quad (2)$$

To illustrate, presume that the average years of paternal education increased by 2.5 years between the NFHS 1996 and NDHS 2016 rounds, thus $\bar{X}_{t=k} - \bar{X}_{t=1} = 2.5$, and that the estimated β coefficient of paternal education from the multivariable OLS model equalled 0.040 ($p < .10$). Multiplying the two components yields 0.10. This indicates that the hypothesised change in paternal education over the 1996–2016 period predicted a 0.10 SD increase in HAZ. We can perform equivalent calculations for other nutrition-sensitive and nutrition-specific drivers of chronic undernutrition to gauge the extent to which a determinant explains changes in child linear growth outcomes over time, as well as how all our time-variant independent variables as a whole (i.e., the models) perform in explaining changes in HAZ and the prevalence of (severe) stunting over time.

To check the robustness of our regression-decomposition results, we performed various additional statistical analyses. First, we tested the differences between our LPM β coefficients and average marginal effects estimated from multivariable logistic regression models for (severe) stunting. Second, to assess the assumption of time-invariant β coefficients, we conducted an Oaxaca-Blinder decomposition testing for systematic differences in β coefficient between the NFHS 1996 and NDHS 2016 rounds (Jann, 2008). Furthermore, we checked the interaction terms between our time-variant covariates and five data rounds to test if associations between predictors and child linear growth outcomes were modified by survey year. Third, we used quantile regressions as an alternative method of exploring potential changes in the importance of our hypothesised nutrition-sensitive and nutrition-specific determinants across different levels of the HAZ

distribution (Block, Masters, & Bhagowalia, 2012). Fourth, as a sensitivity analysis, we conducted separate regression-decompositions for rural and urban samples. Fifth, we estimated models that excluded potentially endogenous health care and demographic variables. Lastly, we tested potential multicollinearity among the time-variant independent variables in the multiple regression models using variance inflation factors (≥ 4).

3 | RESULTS

3.1 | Trends in child linear growth outcomes

Nepal achieved rapid and sustained improvements in mean HAZ (0.84 ± 0.09) and the prevalence of stunting (-24.1 ± 1.5 p.p.) and severe stunting (-17.2 ± 1.1 p.p.) in under-three children over the 1996–2016 period (Table 2). Furthermore, the velocity of child linear growth increments was substantially larger in rural as compared to urban areas. We report a parallel shift in the entire HAZ distribution from the NFHS 1996 to NDHS 2016 rounds suggesting a distribution-neutral improvement in child linear growth over time (Figure 1). The graph of HAZ by child age for the first and last survey rounds indicate statistically significant improvements in linear growth across all ages between 0 and 35 months (Figure 2). Furthermore, our local polynomial smooth plot informs that linear growth faltering in under-three Nepalese children was a result of both small size at birth (the intercept), which in turn implies that maternal malnutrition (Figure S1) is an important constraint, as well as postnatal malnutrition (the slope).

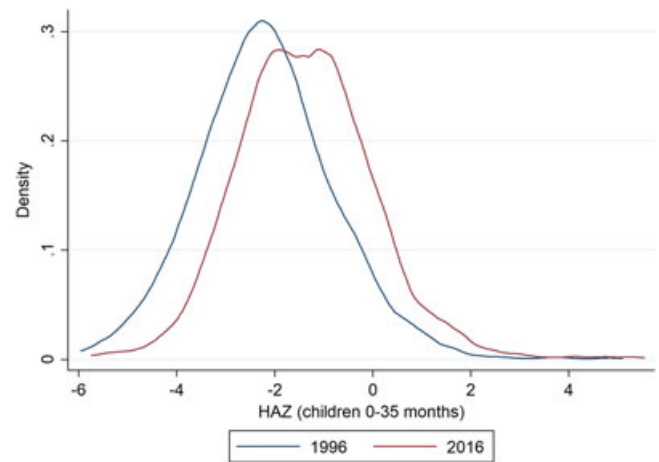


FIGURE 1 Shifts in the distribution of height-for-age z-score (HAZ), 1996 to 2016. Source: Kernel density estimates from Nepal's Family Health Survey 1996 and Nepal Demographic and Health Survey 2016

3.2 | Trends in nutrition-sensitive and nutrition-specific determinants

We present the trends in our hypothesised nutrition-sensitive and nutrition-specific determinants in Table 3. Our findings indicate substantial changes between NFHS 1996 and NDHS 2016 in iron supplementation during pregnancy (778%), childbirth in a medical facility (669%), 4⁺ antenatal care (ANC) visits (661%), bottle-feeding (400%), maternal years of education (373%), prenatal doctor visits (242%),

TABLE 2 Changes in mean height-for-age z-score and stunting prevalence for different samples of under-three children across Nepal's Family Health Survey (NFHS) and four Nepal Demographic and Health Surveys (NDHS)

Sample	HAZ (SD)			Stunting (%) (SD)			Severe stunting (%) (SD)		
	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban
1996	-2.18 (1.41)	-2.21 (1.40)	-1.71 (1.44)	56.6 (0.8)	57.3 (0.8)	45.6 (2.7)	26.9 (0.7)	27.5 (0.7)	17.6 (2.2)
2001	-2.01 (1.39)	-2.04 (1.38)	-1.53 (1.38)	50.4 (0.8)	51.4 (0.9)	36.1 (2.7)	23.8 (0.7)	24.4 (0.7)	14.1 (1.9)
2006	-1.71 (1.41)	-1.77 (1.40)	-1.24 (1.40)	41.9 (0.9)	43.6 (1.0)	28.4 (1.8)	17.2 (0.7)	18.1 (0.8)	10.7 (1.1)
2011	-1.47 (1.45)	-1.52 (1.44)	-0.95 (1.40)	35.0 (1.3)	36.1 (1.5)	23.7 (2.6)	13.8 (0.9)	14.4 (1.1)	7.5 (1.6)
2016	-1.34 (1.40)	-1.46 (1.42)	-1.23 (1.37)	32.5 (1.2)	36.3 (1.9)	29.1 (1.6)	9.7 (0.8)	11.1 (1.3)	8.5 (1.0)
Change	0.84 (0.09)	0.75 (0.06)	0.48 (0.09)	-24.1 (1.5)	-21.0 (2.1)	-16.5 (3.2)	-17.2 (1.1)	-16.4 (1.5)	-9.1 (2.3)
Percent change (%)	38.5	33.9	28.1	-42.6	-36.6	-36.2	-63.9	-59.6	-51.7
N	13,262	11,592	1,670	13,262	11,592	1,670	13,262	11,592	1,670

Source: Authors' estimates from the NFHS 1996 to NDHS 2001–2016 rounds, using sampling weights.

Note. Stunting (%) refers to $HAZ \leq 2$ SD and severe stunting (%) to $HAZ \leq 3$ SD.

Abbreviations: HAZ, height-for-age z-score; SD, standard deviation.

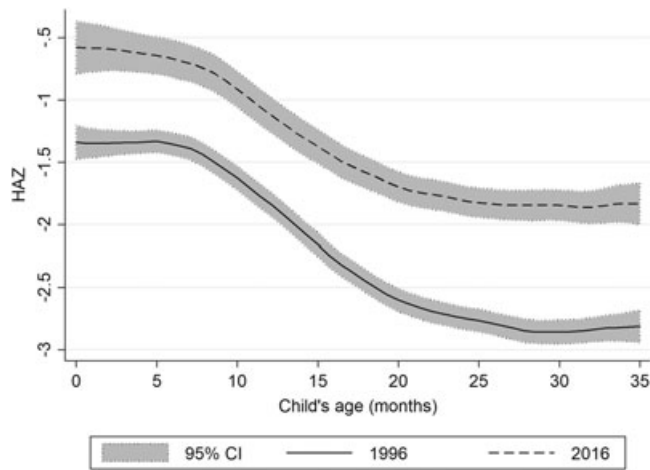


FIGURE 2 Shifts in height-for-age z-score (HAZ), by child's age, from 1996 to 2016. Source: Local polynomial smoothing predictions with 95% CIs estimated from Nepal's Family Health Survey 1996 and Nepal Demographic and Health Survey 2016. CI, confidence interval

early initiation of breastfeeding (EIBF; 204%), household asset index (175%), and children receiving all basic vaccinations (159%). The approximately linear relationships between our continuous time-variant independent variables and HAZ are reported in Figure 3.

3.3 | Regression–decomposition

Our multivariable linear regression models in Table 4—pooled sample from all available survey rounds ($n = 10,880$)—identified various nutrition-sensitive and nutrition-specific determinants that were significantly associated ($p < .10$) with an improved HAZ, including basic child vaccinations (β (SE): 0.11 (0.03); $p = .001$), childbirth in a medical facility (β (SE): 0.11 (0.04); $p = .007$), prenatal doctor visits (β (SE): 0.08 (0.04); $p = .028$), 4⁺ ANC visits (β (SE): 0.07 (0.04); $p = .073$), EIBF (β (SE): 0.05 (0.03); $p = .068$), household asset index (β (SE): 0.04 (0.01); $p < .001$), maternal BMI (β (SE): 0.03 (0.01); $p < .001$) and height ≥ 145 cm (β (SE): 0.51 (0.04); $p < .001$), preceding birth interval (β (SE): 0.02 (0.01); $p = .002$), and maternal (β (SE): 0.02 (0.01); $p < .001$) and paternal (β (SE): 0.01 (0.00); $p < .001$) years of education. Most of the significant time-variant independent variables in our OLS model (HAZ) carried over to either LPM models estimated for stunting and severe stunting. Note that women's decision-making was excluded from all multivariable regression models due to the limited NFHS and NDHS data collected on mother's involvement in household spending ($n = 2,456$).

Table 5 and Figure 4 show the predicted sources of the positive trend in child linear growth observed over time. From the 0.84 ± 0.09 SD increment in mean HAZ, between the NFHS 1996 and NDHS 2016 rounds, health care and service-related variables contributed 0.19 (22.6%) SD, household assets 0.15 (17.9%) SD, and parental education 0.13 (15.5%) SD to the actual nutritional change. Furthermore, maternal BMI and height ≥ 145 cm contributed 0.08 (9.5%) SD, fertility

0.03 (3.6%) SD, and breastfeeding practices 0.02 (2.4%) to the change in HAZ over the past two decades.

Our LPM β coefficients were not significantly different from the marginal effects estimated from logistic regression models. Furthermore, robustness checks at the lower tail of the HAZ distribution, that is, 25th and 50th quantile, yielded similar results to those reported in Table 4. Excluding our health care and fertility variables led to only minor non-significant increases in the β coefficients of household asset index, maternal and paternal years of education, and improved household sanitation. However, our multiple linear regression models performed less well (larger standard errors) in the NDHS 2016 round, when linear growth outcomes were measured for a smaller sample of under-three children, that is, every second household ($n = 1,403$) compared to the NFHS 1996 ($n = 3,703$). We argue that the smaller sample size in the NDHS 2016 round produced this instability, rather than any genuine changes in the β coefficients of the independent variables. Moreover, our interaction terms confirmed that survey round did not significantly modify the associations between the time-variant covariates and child linear growth outcomes (except basic child vaccination and birth order).

4 | DISCUSSION

Over the last two decades, Nepal achieved an average annual increase in HAZ of 0.04 SD and decrease in stunting prevalence of 1.2 p.p. in under-three children, despite the 10-year armed Maoist insurgency (1996–2006) and subsequent period of socioeconomic and political turmoil, including the Gorkha earthquake, transition to federalism, and the 2015 Nepal blockade (2006–2016). Nevertheless, Nepal has unfinished business from the millennium development goals era with stunting rates in 2016 remaining unacceptably high in children under-three (32.5%) and under-five (35.8%). To this end, the GoN endorsed the World Health Assembly's target of 40% fewer stunted children by 2025 and also set a daunting sustainable development goals target to reduce stunting to 15.0% by 2030 (National Planning Commission, 2017). However, at the current annual rate of stunting reduction, it is unlikely that Nepal will achieve these targets (Devkota et al., 2016), without further national scale efforts to accelerate the current child linear growth faltering trend.

Our results provide contextual evidence of the key drivers of Nepal's headway against linear growth faltering in under-three children from 1996 to 2016. First, advances in the utilisation of health care and related services—measured as prenatal doctor visits, 4⁺ ANC visits, iron supplementation during pregnancy, childbirth in a medical facility, and child basic vaccinations—was identified as an important driver in our study, which is consistent with previous research in Nepal (Harding, Aguayo, & Webb, 2018; Headey et al., 2017). We argue that scaled-up nutrition strategies, including the Expanded Program on Immunization (1989), Safe Delivery Incentive Programme (2008), Integrated Management of Neonatal and Childhood Illness (2009), and Community-Based Newborn Care Package (2012), might have contributed to improved neonatal and child health

TABLE 3 Trends in means (SD) for under-three child nutrition determinants, 1996, 2001, 2006, 2011, and 2016

	Asset Index (1–10)	Maternal education (years)	Paternal education (years)	Prenatal doctor visit (%)	4* ANC visits (%)	Iron during pregnancy (%)	Born in a medical facility (%)	Maternal BMI (kg/m ²)	Maternal height ≥145 cm (%)	Early initiation of breastfeeding (%)
1996	2.0 (1.7)	1.1 (2.6)	3.9 (4.1)	13.0 (0.5)	8.4 (0.4)	10.5 (0.5)	8.3 (0.4)	20.0 (2.2)	84.9 (0.5)	18.2 (0.6)
2001	2.4 (2.1)	1.5 (3.0)	4.4 (4.2)	17.0 (0.7)	13.0 (0.6)	23.9 (0.7)	12.1 (0.5)	20.1 (2.4)	85.5 (0.6)	31.2 (0.8)
2006	3.7 (2.7)	2.7 (3.7)	5.3 (4.0)	20.9 (0.7)	26.6 (0.8)	62.8 (0.9)	20.6 (0.7)	20.3 (2.6)	85.9 (0.6)	35.3 (0.8)
2011	4.8 (2.9)	3.8 (4.1)	5.7 (4.0)	27.8 (0.8)	45.1 (0.9)	81.7 (0.7)	42.6 (0.9)	20.8 (2.8)	86.8 (0.9)	45.3 (0.9)
2016	5.5 (2.6)	5.2 (4.3)	6.8 (3.7)	44.4 (0.9)	63.9 (0.9)	92.2 (0.5)	63.8 (0.9)	21.4 (3.4)	89.5 (0.8)	55.3 (0.9)
Change	3.5 (0.1)	4.1 (0.1)	2.9 (0.1)	31.4 (1.1)	55.5 (1.0)	81.7 (0.7)	55.5 (1.0)	1.4 (0.1)	4.6 (1.0)	37.1 (1.1)
Percent change (%)	175.0	372.7	76.3	241.5	660.7	778.1	668.7	7.0	5.4	203.8
N	16,494	17,536	17,177	16,129	17,537	16,220	17,534	14,309	14,342	16,371
	Bottle-feeding (%)	All vaccinations (%)	Birth order (rank)	Preceding birth interval (years)	Open defecation (%)	Water source-piped (%)	Women's decision-making (%)	Ever breastfed (%)	Water source-tube well (%)	Duration of breastfeeding (months)
1996	2.5 (0.3)	33.0 (0.7)	3.3 (2.2)	3.9 (2.1)	86.2 (0.5)	29.0 (0.7)	30.7 (2.4)	93.9 (0.4)	41.4 (0.7)	14.8 (9.6)
2001	2.2 (0.3)	48.3 (0.8)	3.2 (2.1)	4.0 (2.1)	77.8 (0.7)	32.4 (0.8)	34.0 (2.6)	98.4 (0.2)	40.7 (0.8)	15.8 (9.3)
2006	2.6 (0.3)	61.2 (0.9)	2.7 (1.8)	4.4 (2.2)	60.3 (0.9)	34.6 (0.8)	30.3 (1.8)	94.3 (0.4)	41.5 (0.9)	15.9 (9.9)
2011	5.0 (0.4)	62.2 (0.9)	2.5 (1.7)	4.7 (2.2)	49.9 (0.9)	41.2 (0.9)	46.1 (2.3)	96.3 (0.3)	43.0 (0.9)	15.0 (10.1)
2016	12.5 (0.6)	85.3 (0.7)	2.2 (1.5)	5.0 (2.2)	22.1 (0.7)	45.8 (1.0)	46.1 (2.1)	95.6 (0.4)	45.7 (0.9)	15.5 (9.9)
Change	10.0 (0.7)	52.3 (1.0)	-1.1 (0)	1.1 (0.1)	-64.1 (1.0)	16.8 (1.2)	15.4 (3.2)	1.7 (0.5)	4.3 (1.2)	0.7 (0.2)
Percent change (%)	400.0	158.5	-33.3	28.2	-74.4	57.9	50.2	1.8	10.4	4.7
N	16,086	16,836	17,506	17,537	16,508	16,501	2,456	17,531	16,501	16,509

Source: Author's estimates from Nepal's Family Health Survey 1996 and Nepal Demographic and Health Survey 2001, 2006, 2011, and 2016, using sampling weights.

Abbreviations: BMI, body mass index; SD, standard deviation.

[Correction added on 6 November 2020, after first online publication: in Table 3, the column headings on the second part have been corrected.]

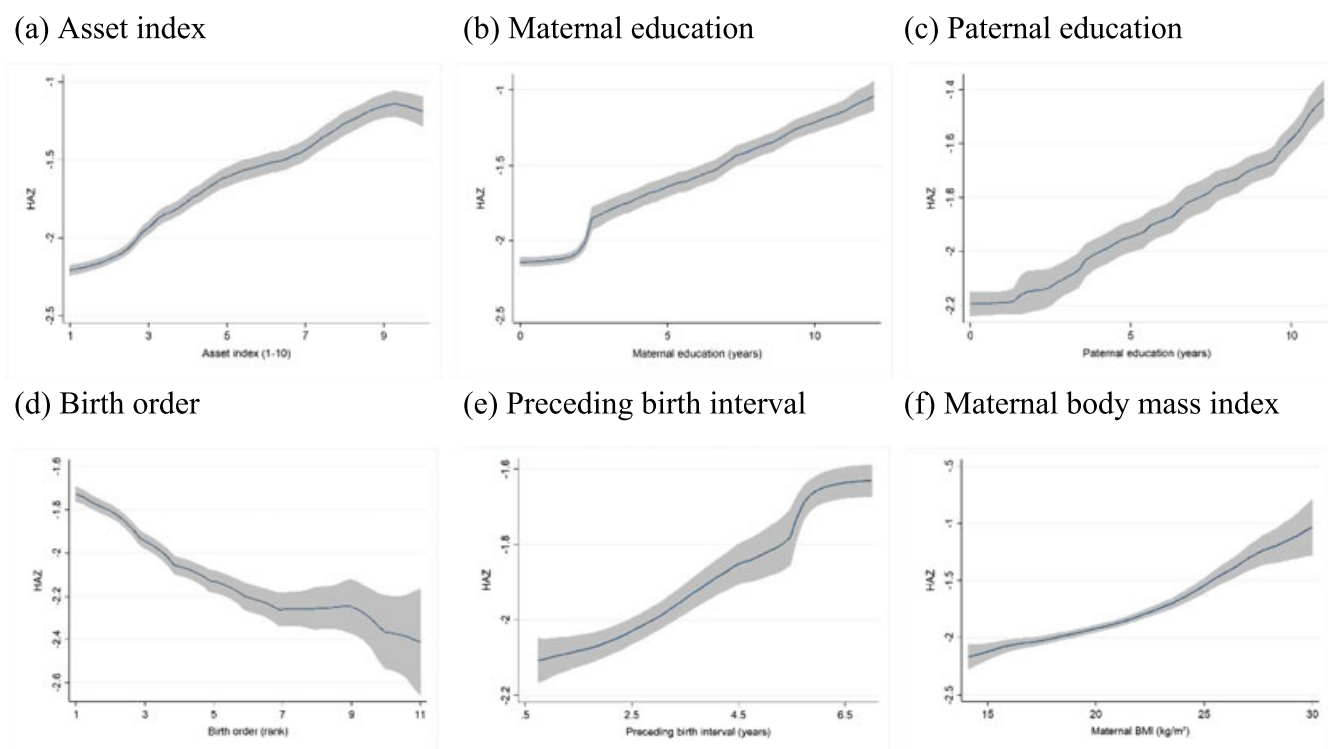


FIGURE 3 Non-parametric estimates of the relationships between height-for-age z-score (HAZ) and continuous variables. Source: Local polynomial smoothing predictions with 95% CI estimated from Nepal's Family Health Survey 1996 and Nepal Demographic and Health Surveys 2001, 2006, 2011, 2016. CI, confidence interval

over the study period (Paudel, Shrestha, Siebeck, & Rehfuess, 2013, 2017). Furthermore, the GoN recently increased the budget for primary health care and increased the number of grassroots outreach clinics, leading to expansions in child vaccinations, micronutrient supplementation, and prenatal, neonatal, and postnatal care (including nutritional advice), and treatment of common childhood diseases (Nepali, Simkhada, & Davies, 2019). Second, household asset accumulation emerged as an important driver of improved HAZ and stunting prevalence, findings which are corroborated by both cross-country analyses (Argaw et al., 2019; Headey, 2013; Milman, Frongillo, de Onis, & Hwang, 2005) and trend analyses of national success stories (Headey et al., 2015, 2017; Zanello, Srinivasan, & Shankar, 2016). Furthermore, our results are in line with the World Bank PovcalNet analysis tool, which showed that Nepal achieved significant increases in household income and reductions in poverty rates from 64% to 15% between 1996 and 2016 (The World Bank, 2019). Nevertheless, Nepal remains one of the poorest and slowest growing economies in Asia. National-level economic progress has been shown to facilitate larger household food expenditures, maternal and child care, and improved access to public health care and related services (Vollmer et al., 2014). Third, in parallel to other cross-sectional studies in LMIC (Alderman & Headey, 2017; Kim, Mejía-Guevara, Corsi, Aguayo, & Subramanian, 2017), parental educational gains emerged as a driver of improved child linear growth outcomes over the past 20 years. Improved education not only contributes to strengthening a household's capacity to generate income

and smooth shocks but might also result in enhanced health and nutrition knowledge, greater access to and use of health care services, improved infant and young child feeding (IYCF) practices, and enhanced women's decision-making within the household (Carlson, Kordas, & Murray-Kolb, 2015). In the last decade, the GoN doubled public spending on education from 10% in 1988–1992 to 20% in 2006–2011 (The World Bank, 2010). Furthermore, Nepal implemented various reformative actions, including the Education for All Program (2004–2009), National Literacy Campaign in 2008, School Sector Reform Plan (2009–2016), and the provision of scholarships to all girls from 2010 to 2011 onwards (Angdembe et al., 2019). Fourth, our statistical decompositions identified improved household sanitation coverage as a potential driver of the decreased stunting trend from 1996 to 2016. Our findings are supported by a growing body of literature indicating enteric dysfunction, resulting from poor water, sanitation, and hygiene (WASH), is among the most critical factors for the high burden of child stunting in developing countries (Guerrant, Deboer, Moore, Scharf, & Lima, 2013; Lin et al., 2013). Over our study time frame, Nepal achieved sizeable improvements in sanitation, in particular the reduction of household-level open defecation (%) (Hathi, Haque, Pant, Coffey, & Spears, 2017). The subsidised construction of low-cost toilet and latrine facilities, through Community-Led Total Sanitation and the Hygiene and Sanitation Master Plan (2011–2015), not only decreased open defecation (%) rates, but also facilitated changes in behaviour within communities (Headey & Hoddinott, 2015).

TABLE 4 Determinants of under-three child linear growth outcomes in pooled regression models

Regression number	1	2	3
Dependent variable	HAZ (SE)	Stunting (SE)	Severe stunting (SE)
Estimator	OLS	LPM	LPM
Asset index (1–10)	0.042*** (0.008)	–0.011*** (0.003)	–0.007*** (0.002)
Maternal education (years)	0.021*** (0.005)	–0.007*** (0.002)	–0.001 (0.001)
Paternal education (years)	0.014*** (0.004)	–0.003* (0.002)	–0.003*** (0.001)
Prenatal doctor visit (0/1)	0.081** (0.037)	–0.006 (0.014)	–0.017 (0.010)
4 ⁺ ANC visits (0/1)	0.066* (0.037)	–0.032** (0.014)	–0.007 (0.010)
Iron during pregnancy (0/1)	–0.006 (0.034)	0.005 (0.013)	–0.015 (0.011)
Born in a medical facility (0/1)	0.105*** (0.039)	–0.032** (0.014)	–0.004 (0.011)
Maternal BMI (kg/m ²)	0.035*** (0.005)	–0.009*** (0.002)	–0.005*** (0.002)
Maternal height (0/1)	0.509*** (0.035)	–0.138*** (0.013)	–0.132*** (0.012)
All vaccinations (0/1)	0.109*** (0.034)	–0.029** (0.013)	–0.063*** (0.012)
Birth order (rank)	0.007 (0.012)	–0.005 (0.004)	0.003 (0.004)
Preceding birth interval (years)	0.023*** (0.007)	–0.009*** (0.003)	–0.004* (0.002)
Open defecation (0/1)	–0.039 (0.035)	0.034** (0.014)	0.004 (0.011)
Water source–tube well (0/1)	–0.062 (0.066)	0.008 (0.024)	–0.010 (0.019)
Water source–piped (0/1)	–0.011 (0.039)	0.004 (0.015)	–0.006 (0.012)
Early initiation of breastfeeding (0/1)	0.050* (0.027)	–0.011 (0.010)	–0.023*** (0.008)
Duration of breastfeeding (months)	–0.001 (0.008)	0.002 (0.003)	–0.003 (0.003)
Ever breastfed (0/1)	–0.240 (0.362)	–0.030 (0.076)	–0.043 (0.066)
Bottle-feeding (%)	–0.054 (0.070)	0.023 (0.024)	0.021* (0.017)
R ²	.396	.307	.241
N	10,880	10,880	10,880

Source: Author's estimates.

Note. Stunting refers to HAZ \leq 2 SD and severe stunting to HAZ \leq 3 SD. The regressions include a number of omitted time-invariant controls, including regional and agroecological fixed effects for seven groups, an

urban dummy, dummy variables for religion and ethnicity, dummy variables for various brackets of maternal age (in 5-year intervals), dummy variables of child age (monthly), a child sex dummy, and dummy variables for stratum and Family Health Survey and Demographic and Health Surveys round. See Table 1 for definitions of time-variant variables. Abbreviations: HAZ, height-for-age z-score; LPM, linear probability model with a robust variance estimator; OLS, ordinary least squares; SE, standard error.

*significant at the 10% level.

**significant at the 5% level.

***significant at the 1% level.

It is important to note that NFHS and NDHS data (Figure 2) suggest that child linear growth deficits stem from both poor birth outcomes (Leroy & Frongillo, 2019) and postnatal growth trajectories between 6 and 23 months (Victora et al., 2010). Therefore, our observed progress on HAZ and stunting prevalence might be attributed to transgenerational improvements in maternal nutrition (Addo et al., 2015)—captured in our models by enhanced iron supplementation during pregnancy, maternal BMI and height (Hasan, Magalhães, Williams, & Mamun, 2016), and reduced maternal reproductive burden (birth order and birth interval)—and improvements in

TABLE 5 Decomposition of predicted changes in child linear growth outcomes, 1996 to 2016

Dependent variable	HAZ	Stunting (%)	Severe stunting (%)
Asset index (1–10)	0.15	–3.9	–2.5
Maternal education (years)	0.09	–2.9	
Paternal education (years)	0.04	–0.9	–0.9
Prenatal doctor visit (%)	0.03		
4 ⁺ ANC visits (%)	0.04	–1.7	
Born in a medical facility (%)	0.06	–1.8	
Maternal BMI (kg/m ²)	0.05	–1.3	–0.7
Maternal height (%)	0.03	–0.6	–0.6
All vaccinations (%)	0.06	–1.5	–3.3
Preceding birth interval (years)	0.03	–1.0	–0.4
Open defecation (%)		–2.2	
Early initiation of breastfeeding (%)	0.02		–0.9
Bottle-feeding (%)			0.2
Predicted nutritional change	0.60	–17.8	–9.1
Actual nutritional change	0.84	–24.1	–17.2
Explanatory power of model (%)	71.4	73.9	52.9

Source: Author's estimates.

Note. Predicted nutritional change is based on a linear decomposition at means, in which changes in the mean of each time-variant variable (Table 3) is multiplied by the corresponding β coefficient (Table 4). Stunting (%) refers to HAZ \leq 2 SD and severe stunting to HAZ \leq 3 SD. Abbreviation: HAZ, height-for-age z-score.

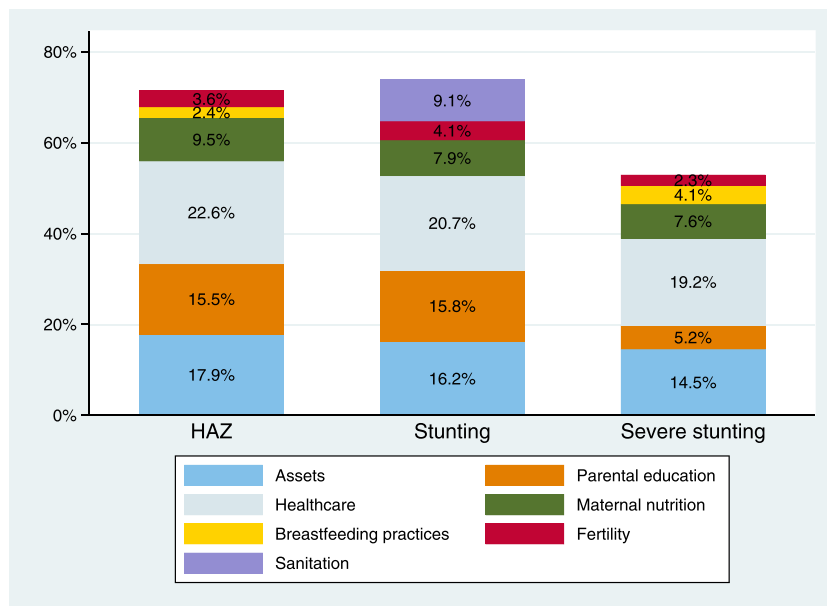


FIGURE 4 Estimated contributions of nutrition-sensitive and nutrition-specific determinants to changes in child linear growth outcomes, from 1996 to 2016. Source: Author's estimates from Nepal's Family Health Survey 1996 and Nepal Demographic and Health Surveys 2001, 2006, 2011, 2016. HAZ, height-for-age z-score

postnatal child care and feeding practices (Na et al., 2018), as indicated by the substantial increase in EIBF. Furthermore, advances in the spectrum of age-appropriate IYCF practices, not covered due to data constraints, have been reported in Nepal over the past two decades (Benedict, Craig, Torlesse, & Stoltzfus, 2018; Hanley-Cook, Argaw, Dahal, Chitekwe, & Kolsteren, 2022). These positive child caring trends might be attributed to scaling up nutrition-specific strategies advocating for optimal IYCF (Cunningham et al., 2017; Locks et al., 2018) and national policy, such as the National Safe Motherhood Policy (1998), National Policy on Skilled Birth Attendants (2006), and National IYCF Strategy (2014; Karn, Devkota, Uddin, & Thow, 2017). Our lack of associations between prolonged breastfeeding and child linear growth outcomes have been reported previously in resource-poor settings, characterised by limited access to diverse complementary foods. These findings might be explained by reverse causality, that is, mothers and infants with poor health and growth deciding to continue breastfeeding for a longer period (Habicht, 2002; Simondon, Simondon, Costes, Delaunay, & Diallo, 2001).

At national level, Nepal has increased multisectoral efforts to break the intergenerational cycle of chronic child malnutrition, in the form of nutrition-sensitive interventions and awareness campaigns linking undernutrition with WASH, social protection, and agriculture under the common framework of the MSNP I (2013–2017) and integrated nutrition programmes such as Suaahara I (2011–2016; Cunningham, Singh, et al., 2017). However, recent nutrition strategies are unlikely to have had any impact prior to implementation and thus earlier progress on child linear growth faltering, between 1996 and 2011, might be attributed to national implementation of more single-sector policies. These include Nepal's National Plan of Action on Nutrition (1998), National Nutrition Policy and Strategy (2004 and its amendment in 2008), and National School Health and Nutrition Strategy (2006). Yet evidence suggests that Nepal's policy actions might not be widespread enough (e.g., MSNP I, 2013–2017, was only

implemented in six model districts by 2015) to reach the most vulnerable and impoverished populations most affected by malnutrition (Angdembe et al., 2019; Webb et al., 2016). In Nepal, access to resources and services, political representation, and the presence of opportunity is often unequal due to both geographic isolation and long-standing social and economic inequalities (Cunningham, Singh, et al., 2017; Devkota et al., 2016; Nepali et al., 2019).

Our analysis has several strengths. We used the most recent national-level data from five surveys spanning two decades. Furthermore, our analysis was comprehensive in examining a wide range of consistently measured child linear growth outcomes and available nutrition-sensitive and nutrition-specific determinants. Our models also had substantial predictive power, suggesting that the time-variant variables used in the analysis might be useful for monitoring and evaluation of national nutrition initiatives to reduce childhood undernutrition. Moreover, our findings were robust to a variety of statistical checks. On the other hand, the cross-sectional nature of our data infers that our analysis is ecological and causality might be hampered by omitted confounding. Furthermore, it was not possible to consider the time lag between determinants and child linear growth outcomes, as our study was entirely based on NFHS and NDHS data sets, where independent and dependent variables were collected at the same time. However, experimental designs, such as randomised controlled trials, are in general not well suited to identify the impacts of multiple nutrition-sensitive sectors and integrated at-scale interventions on chronic child undernutrition. Hence, elucidating national-level success stories requires trade-offs between internal and external validity. In addition, comparability is essential in regression-decomposition approaches and thus constrained our analysis to use variables that were available across all five survey rounds. To illustrate, in particular for nutrition-specific factors, comprehensive data on age-specific IYCF indicators were absent for the NFHS 1996 and early NDHS rounds (Hanley-Cook et al., 2022), which limited their inclusion in our

analysis. Moreover, potential limitations of the explanatory variables in our linear regression models should also be recalled, including the fact that household asset indices fail to account for a durable's age and depreciation (Harttgen & Vollmer, 2013), improved health care coverage might not necessarily imply high-quality services (Acharya, Sharma, Dulal, & Aryal, 2018), water sources do not specifically capture water quality (Klasen, Lechtenfeld, Meier, & Rieckmann, 2012), improved sanitation might be better captured at the community level (Spears, 2013), EIBF and bottle-feeding strictly apply to children aged 0–23 months, and duration of breastfeeding is ideally captured as a median at population level (WHO, 2008, 2010). Moreover, we note that drivers of improved child linear growth outcomes over the past 20 years may not guarantee future success in Nepal, due to possible changes in (nonlinear) indicator–HAZ relationships and a scope for saturation in nutrition-sensitive or nutrition-specific determinants (Argaw et al., 2019; Headey et al., 2017).

In conclusion, our study reiterates the complex and multifactorial nature of child linear growth faltering. Furthermore, in Nepal, the rapid and sustained progress on child linear growth outcomes, over the 1996–2016 period, stemmed from advances in multiple nutrition-sensitive and nutrition-specific factors over time. Therefore, monitoring multisectoral policies and integrated programmes on chronic undernutrition ought to cover a broad range of distal socioeconomic factors, rather than a narrow focus on proximal nutrition-specific indicators only. Our findings advocate for coherent multisectoral nutrition strategies to continue the positive trend against child linear growth faltering in Nepal.

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CONFLICTS OF INTEREST

PD, SC, and SR are members of UNICEF. RPB and KRP are members of Nepal's Ministry of Health and Population. The authors alone are responsible for the views expressed in this publication and declare that they have no conflicts of interest.

CONTRIBUTIONS

GH-C, AA, and PK performed the research. GH-C, AA, PD, and PK designed the research study. GH-C and AA analysed the data. GH-C, AA, PD, SC, SR, RPB, and KRP wrote the paper.

DATA AVAILABILITY STATEMENT

All our data are based on Demographic and Health Surveys, which are available at the Measure DHS website after appropriate registration: <http://dhsprogram.com/data/available-datasets.cfm>.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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