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RESEARCH

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Determinants of height-for-age Z-score (HAZ) among Ethiopian children aged 0–59 months: a multilevel mixed-effects analysis

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Abstract

Background Height-for-age z-score (HAZ), based on WHO Child Growth Standards, measures linear growth in children, with lower values indicating potential undernutrition. This study examines HAZ as a continuous measure to explore its proximal and distal determinants.

Methods Data from 5,045 children aged 0–59 months from the 2019 Ethiopian Mini Demographic and Health Survey were used. The survey employed a stratified two-stage cluster design. A multilevel mixed-effects linear regression model was applied to estimate the associations between HAZ and various proximal (individual and household-level) and distal (community-level) factors. Proximal factors included child age, sex, early breastfeeding, maternal age, education, age at first birth, maternal literacy, delivery place, number of children under-five, household size, wealth index, media access, household head sex, cooking fuel, toilet type, and water source. Distal factors included urban/rural residence, altitude, and capital city residence. Effect sizes were reported as unstandardized beta coefficients (β) with 95% confidence intervals (CI).

Results The mean HAZ was − 1.26 (SD = 1.47). The mean age of the children was 28.9 months, and 36.23% of mothers were literate. Child age was inversely associated with HAZ, with each additional month linked to a 0.02 unit reduction (β = -0.02; 95% CI: -0.024, -0.016; $p < 0.001$). Maternal age and education were positively associated with HAZ, with each additional year of maternal age linked to a 0.015 unit increase ($\beta = 0.015$; 95% CI: 0.003, 0.026; $p = 0.012$) and each additional year of education associated with a 0.036 unit increase ($\beta = 0.036$; 95% CI: 0.009, 0.062; $p = 0.008$). Higher altitude was associated with a 0.21 unit reduction in HAZ per 1000 m increase (β = -0.21; 95% CI: -0.34, -0.07; $p = 0.003$). Residence in the capital city was associated with a 0.388 unit increase in HAZ ($\beta = 0.388$; 95% CI: 0.093, 0.683; $p = 0.01$).

Conclusion Key determinants of HAZ include child age, maternal age, education, altitude, and capital city residence. These findings highlight the need for multifaceted interventions to improve child linear growth. Enhancing maternal education is a crucial strategy to improve child HAZ scores in Ethiopia.

Keywords Linear growth, Height-for-age z-score (HAZ), Chronic malnutrition, Demographic and health survey, Children under-5, Ethiopia

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Introduction

Height-for-age z-score (HAZ) of less than −2 standard deviations (SD) from the median of the 2006 World Health Organization (WHO) growth standard reflects chronic undernutrition and is defined as stunting [1]. However, linear growth retardation, which refers to child being shorter than expected for their age, does not necessarily imply stunting. As a result, the number of children affected by linear growth retardation is greater than those officially identified as stunted [2]. As of 2022, approximately 22.3% of children under five years old globally were stunted, reflecting chronic undernutrition and its long-term effects on growth and development [3]. In Ethiopia, this figure stood at 37% in 2019 [4].

Although HAZ is widely used to assess stunting, its validity as a binary classifier is debated [5–8]. The −2SD threshold lacks biological justification which makes its use as an individual classifier of stunting poor [7]. Moreover, applying this threshold to populations with shorter average heights may lead to an overestimation of stunting prevalence [9–12]. In an optimal healthy environment, approximately 2.5% of children would naturally fall below this threshold [2, 9]. The binary classification approach not only oversimplifies the complex social and environmental factors influencing growth but may also shift public health efforts toward individual dietary interventions rather than addressing broader systemic issues [2]. Furthermore, relying on this threshold to monitor progress may obscure true improvements in child health due to natural population variations and measurement inaccuracies [13].

Stunting and linear growth retardation result from multifaceted and poorly understood causes, posing challenges for effective intervention design [14–16]. Identifying the factors associated with these conditions is essential for developing targeted strategies. While conventional studies have often treated stunting as a binary outcome, this approach risks overlooking important variations in growth patterns and reducing statistical power [17]. Analyzing HAZ as a continuous variable provides a more comprehensive assessment of child growth, allowing for the identification of risk factors across the full growth spectrum — including those affecting children who may not yet meet the stunting threshold.

This study aims to address this gap by investigating the determinants of HAZ among Ethiopian children under five using data from the 2019 Ethiopian Mini Demographic and Health Survey (EMDHS) [4]. By employing multivariable regression analysis, we seek to identify both proximal and distal factors influencing HAZ. The findings are intended to guide tailored interventions and improve resource allocation, ultimately contributing to efforts to reduce chronic undernutrition.

Methodology

Study design and data source

This study utilized a cross-sectional design using secondary data from the 2019 EMDHS conducted by the Central Statistical Agency (CSA) of Ethiopia. The EMDHS is a nationally representative survey that collects comprehensive data on demographic, health, and nutritional indicators. The survey follows a stratified two-stage cluster sampling design to ensure representativeness at both national and sub-national levels [4].

Study population and setting

The study population comprised children under the age of five residing in Ethiopia at the time of the survey. The 2019 EMDHS children recode (Kid's Recode 'KR') dataset included information on 5,753 children, one record per child. However, we excluded cases with incomplete height or age data ($n = 627$) and other flagged cases ($n = 81$) due to issues such as missing or unknown birth month or year, and out-of-range height-for-age z-scores (HAZ). This resulted in a final analytic sample of 5,045 children. The study was conducted across all regions of Ethiopia, covering both urban and rural areas to ensure broad population representation [4].

Study variables

The dependent variable, height-for-age z-score (HAZ), was analyzed as a continuous variable to capture the full range of growth outcomes, including both stunted (HAZ < -2) and non-stunted children. HAZ values were computed using the WHO Child Growth Standards, which provide a standardized method for assessing child growth [1]. The independent variables included a range of proximal (individual and household) and distal (community) factors, summarized in Table 1. Clean cooking fuel was defined as the use of electricity, liquefied petroleum gas (LGP), natural gas and/or biogas. Literacy was defined as the ability to read parts or the whole of a sentence. Community-level factors included cluster characteristics such as altitude, urban/rural residence, and residence in the capital city.

Statistical analysis

Unweighted descriptive statistics were used to summarize the data. Continuous variables were reported as means and standard deviations, while categorical variables were presented as frequencies and percentages. Variables with high levels of missing data—such as vaccination status ($n = 3{,}240$), vitamin A supplementation ($n = 2{,}088$), and antenatal care visits ($n = 1{,}478$)—were excluded from the analysis to maintain data quality (Additional file 1).

Multicollinearity was assessed using the variance inflation factor (VIF). Initially, solid cooking fuel (VIF = 14.64)

Table 1 List of independent variables in this study categorized

Proximal Factors		Distal factors
Age of child in months	Number of ANC visits	Residence
Sex of child	Place of delivery	Altitude in meters
Early initiation of breastfeeding	Number of children under 5	Living in the capital
Mother's age in years	Number of household members	
Mother's education in years	Wealth index	
Mother's age at first birth	Household owns radio	
Is mother literate	Household owns TV	
Religion of the mother	Household access to electricity	
Uses open defecation	Sex of household head	
Improved source of drinking water	Type of fuel for cooking	

ANC: Antenatal Care

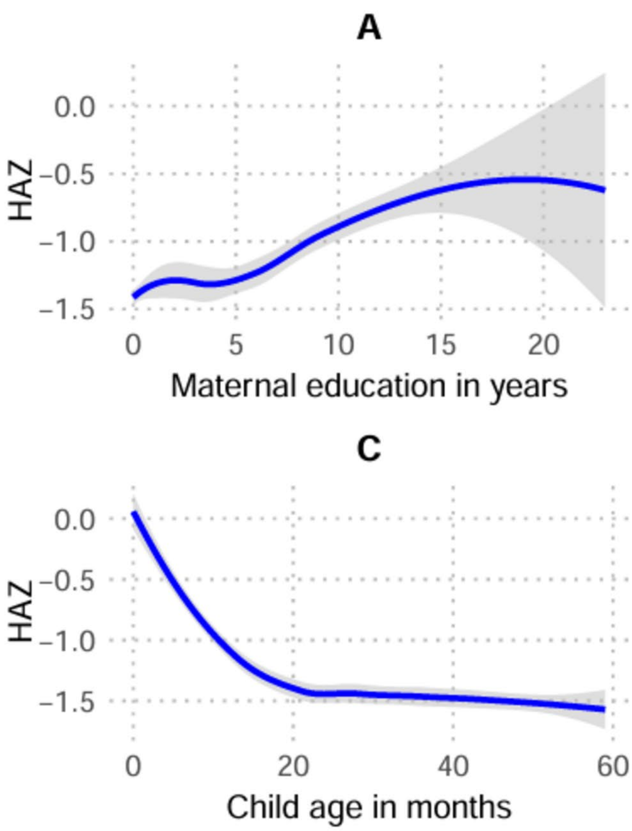

Fig. 1 Height-for-age z-score (HAZ) in Ethiopian children aged 0–59 months by child age, maternal age, education and altitude, 2019 EMDHS. Shaded areas represent 95% confidence intervals from locally estimated scatterplot smoothing (LOESS)

and clean cooking fuel (VIF = 14.35) showed high multicollinearity. Removing solid cooking fuel reduced the VIF for clean cooking fuel to 2.34. The wealth index (VIF = 11.67) also showed high correlation with other variables. To address this, variables with theoretical overlap and high VIF values—such as television ownership (VIF = 3.62), electricity (VIF = 2.79), and flooring type (VIF = 2.76)—were sequentially removed, reducing the VIF for the wealth index to 5.52. Birth order (VIF = 5.16) was also excluded to minimize multicollinearity (Additional file 1). After these adjustments, the mean VIF was reduced to 1.83. Wealth was retained despite a VIF of 5.52 due to its theoretical importance, though its significance diminished in the full model. All analyses were conducted using Stata version 15. R studio (version 4.3.3) was used to create Fig. 1. The R code is available at https://github.com/NebyuDanielAmaha/HAZ.

Model Building

A two-level hierarchical mixed-effects model was used to analyze the determinants of HAZ among Ethiopian children under five. The EMDHS sampling design follows a stratified two-stage cluster approach, with enumeration areas (EAs or clusters) selected in the first stage and households within clusters selected in the second stage. This design creates a hierarchical structure where individual children (Level 1) are nested within clusters (Level 2), violating the assumption of independence in ordinary linear regression. The mixed-effects model addresses this by incorporating a random intercept for clusters, allowing for the estimation of HAZ variability at the cluster level and accounting for within-cluster correlation.

To account for the complex sampling design, the sample weight ('v005') was applied following DHS guidelines (sample weight = v005/100,000). Although Stata issued a warning about the absence of cluster-level weighting, DHS sample weights reflect individual-level selection probabilities and are appropriate for this type of analysis.

The final model is specified as:

$$HAZ_{ij} = \beta_0 + \beta_1 X_{ij} + \beta_2 Z_{ij} + u_{0j} + \in_{ij}$$

Where:

- HAZ_{ij} = Height-for-Age Z score for child *i* in cluster *j*.
- X_{ij} = Proximal predictors;
- Z_{ij} = Distal predictors;
- β_0 = overall intercept for HAZ.
- β1, β2 = Coefficients for the respective predictors.
- u_{0j} = random intercept for cluster j (cluster-level variation).
- $\in_{ij}$ = individual-level residual error (unexplained variation).

Three models were specified to assess the contribution of different predictor sets:

1. Model 0 (Null Model): Included only the intercept and random effect to estimate the variance in HAZ attributable to clusters.
2. Model 1 (Base Model): Included proximal factors;
3. Model 2 (Full Model): Added distal factors.

Model fit was evaluated using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). While BIC favored Model 1, Model 2 was retained as the final model because adding altitude and living in the capital city significantly improved explanatory power and biological interpretability. The reduction in AIC and the drop in cluster variance further confirm that Model 2 captures meaningful variation, justifying its selection despite the slight increase in BIC.

Table 2 Sociodemographic characteristics of children under 5 and their mothers from the 2019 Ethiopian Mini demographic health survey (EMDHS) (*n* = 5,045)

Variable (category)	Frequency	%
Sex of child (Male)	2,581	51.16
Early initiation of breastfeeding? (Yes)	2,734	54.19
Is mom able to read and write? (Yes)	1,828	36.23
Delivered at health facility? (Yes)	2,423	48.07
Living in urban area? (Yes)	1,163	23.05
Water source improved? (Yes)	3,278	64.98
Use open defection as toilet facility? (Yes)	2,080	41.23
Household has radio? (Yes)	1,250	24.97
Household has TV? (Yes)	905	18.07
Household has access to electricity? (Yes)	1,443	28.82
Household head a man? (Yes)	4,059	80.46
Uses clean fuel for cooking? (Yes)	385	7.63
Uses solid fuel for cooking? (Yes)	4,595	91.08
Is the floor earth or dung? (Yes)	3,839	76.67
Living in the capital? (Yes)	256	5.07
Mother a non-Christian? (Yes)	2,609	51.71
Continuous Variable	**Mean**	**SD**
Child's age (months)	28.9	17.1
Child's birth order	3.68	2.4
Mother's age (years)	28.7	6.34
Mother's education (years)	3.12	4.37
Number of ANC visits during pregnancy	2.93	2.3
Number of children under 5 in household	1.83	0.8
Number of household members	6.16	2.37
Altitude of household (meters)	1542.3	686.9
Wealth index score of household	-0.22	0.89
Age of mother at 1st birth	18.62	4.16
Height-for-age Z-score (HAZ)	-1.26	1.47

SD: Standard Deviation

Results

Sociodemographic characteristics

A total of 5,045 children and their mothers were included in the analysis. The mean age of children was 28.9 months, and 51.16% were male. Early initiation of breastfeeding was reported for 54.19% of children. Maternal literacy was limited, with only 36.23% of mothers able to read. Health facility deliveries occurred in 48.07% of cases. Household characteristics included urban residency in 23.05% of households, access to improved water sources for 64.98%, and open defecation practices in 41.23%. Regarding household amenities, 28.82% had electricity, 24.97% had a radio, and 18.07% had a television. The mean maternal age was 28.7 years (SD = 6.34), with an average of 3.12 years of formal education (SD = 4.37). Households had a mean of 6.16 members (SD = 2.37), and the mean household altitude was 1,542.3 m (SD = 686.9). The overall mean height-for-age Z-score (HAZ) was − 1.26 (SD = 1.47) (Table 2).

Multi-level regression

The final multilevel mixed-effects linear regression model identified several significant factors associated with children's HAZ. Child age was negatively associated with

HAZ, with each additional month of age linked to a 0.02 decrease in HAZ (β = -0.02; 95% CI: -0.024, -0.016; $p < 0.001$). Conversely, maternal age and education were positively associated with HAZ. Each additional year of maternal age was associated with a 0.015 increase in HAZ ($\beta = 0.015$; 95% CI: 0.003, 0.026; $p = 0.012$), and each additional year of maternal education was associated with a 0.036 increase in HAZ ($\beta = 0.036$; 95% CI: 0.009, 0.062; $p = 0.008$). Higher altitude was associated with a decrease in HAZ (β = -0.21 per 1000 m; 95% CI: -0.34, -0.07; $p = 0.003$), while residing in the capital city was associated with an increase in HAZ ($\beta = 0.388$; 95% CI: 0.093, 0.683; $p = 0.01$). Child sex, breastfeeding initiation, maternal literacy, household wealth, place of residence (urban/rural), toilet facility type, water source, cooking fuel type, household head sex, household size, number of children under 5, delivery location, maternal religion, and maternal age at first birth were not significantly associated with HAZ ($p > 0.05$) (Table 3).

Figure 1 illustrates the relationships between HAZ and key demographic factors. Panel A shows a curvilinear relationship between maternal education and HAZ, showing an initial increase in HAZ that plateaus at higher education levels, suggesting a positive association up to a threshold. Panel B shows a relatively stable association between maternal age and HAZ. Panel C depicts a significant decline in HAZ with increasing child age, particularly from infancy to early childhood, reflecting growth faltering over time. Panel D portrays a negative association between altitude and HAZ. The shaded areas represent 95% confidence intervals derived from locally estimated scatterplot smoothing (LOESS), indicating moderate variability in these associations (Fig. 1).

Model fit parameters

Model fit improved progressively with the inclusion of predictors, as evidenced by the increase in log-likelihood from − 8550.2 in the null model (Model 0) to -8289.4 in the full model (Model 2). AIC favored Model 2, suggesting that the inclusion of distal factors improved predictive accuracy. In contrast, BIC preferred Model 1, reflecting a preference for a simpler model with fewer parameters. Given the study's focus on capturing the contribution of distal factors, AIC was prioritized (Table 4).

The intra-class correlation coefficient (ICC) decreased from 8.23% in Model 0 to 7.46% in Model 2, indicating a reduction in the proportion of HAZ variance attributable to cluster differences as more predictors were added. Model 1, which included proximal factors, showed a slight increase in ICC to 8.53%, despite reductions in cluster and residual variances, suggesting improved within-cluster explanation. The addition of distal factors in Model 2 further reduced cluster variance to 0.1298, an 18.06% reduction from Model 0. Notably, the largest reduction (13.58%) occurred after including altitude, capital residency, and urban/rural residence, highlighting the significant role of these distal factors in explaining community-level variations in HAZ (Table 4).

Table 3 Multilevel analysis of factors associated with Height-for-age Z-score (HAZ) among children aged 0–59 months in Ethiopia ($n = 5{,}045$)

	Model 1		**Model 2**	
	β (95% CI)*	***p-value***	**β (95% CI)**	***p-value***
Age of child in months (0–59)	-0.02 (-0.024;-0.016)	< 0.001	-0.02 (-0.024;-0.016)	< 0.001
Sex of child (Female)	0.067 (-0.046;0.179)	0.245	0.068 (-0.044;0.18)	0.231
Breastfeeding initiated early? (No)	0.112 (-0.007;0.231)	0.066	0.106 (-0.014;0.226)	0.083
Maternal age in years	0.014 (0.003;0.025)	0.016	0.015 (0.003;0.026)	0.012
Maternal education in years	0.035 (0.008;0.062)	0.01	0.036 (0.009;0.062)	0.008
Age of mother at first birth	-0.006 (-0.023;0.01)	0.468	-0.007 (-0.024;0.009)	0.399
Is the mother literate (Yes)	-0.143 (-0.322;0.035)	0.116	-0.151 (-0.331;0.028)	0.099
Religion of mother Christian? (No)	0.244 (0.024;0.464)	0.03	0.173 (-0.053;0.4)	0.134
Place of delivery at health facility (No)	-0.007 (-0.171;0.157)	0.932	-0.007 (-0.17;0.155)	0.93
Number of children under 5 in household	0.062 (-0.027;0.151)	0.172	0.054 (-0.035;0.142)	0.232
Number of household members	-0.02 (-0.05;0.01)	0.191	-0.021 (-0.052;0.009)	0.166
Wealth index score	0.272 (0.083;0.461)	0.005	0.212 (-0.027;0.452)	0.082
Household owns radio? (Yes)	0.036 (-0.11;0.182)	0.633	0.043 (-0.106;0.192)	0.572
Sex of household head (Female)	0.079 (-0.084;0.241)	0.342	0.049 (-0.113;0.211)	0.552
Uses clean fuel for cooking? (Yes)	-0.15 (-0.447;0.147)	0.321	-0.189 (-0.49;0.112)	0.219
Is source of water improved? (Yes)	-0.092 (-0.259;0.076)	0.283	-0.083 (-0.249;0.083)	0.326
Uses open defecation as toilet? (Yes)	0.035 (-0.115;0.186)	0.645	0.009 (-0.144;0.163)	0.904
Place of residence (Rural)			-0.104 (-0.397;0.19)	0.489
Altitude in thousand meters above sea level			-0.21(-0.34;-0.07)	0.003
Living in the capital city? (Yes)			0.388 (0.093;0.683)	0.01

Table 4 Random-effects parameters and multilevel mixed-effects linear regression model fit comparison of stunting in Ethiopian children aged under-5 using the 2019 Ethiopian Mini demographic and health survey (EMDHS)

	Model 0	Model 1	Model 2
degrees of freedom	3	20	23
Cluster variance	0.1584	0.1502	0.1298
Residual variance	1.764	1.610	1.610
ICC (%)	8.23	8.53	7.46
Log-likelihood	-8550.2	-8298.7	-8289.4
AIC	17106.4	16639.8	16626.7
BIC	17125.9	16776.5	16783.4

ICC: Intra-class Correlation; AIC: Akaike Information Criterion; BIC: Bayesian Information Criterion

Discussion

This study identified child age, maternal age and educational level, altitude above sea level and living in the capital to be significant predictors of height-for-age z-score. Low HAZ score remains a critical public health challenge in Ethiopia, with consistently high prevalence despite numerous interventions [18]. Previous research has mainly classified HAZ into stunted (<-2 SD) and non-stunted (≥-2 SD) categories, potentially overlooking the full range of variation in child growth. This study addressed that gap by analyzing HAZ as a continuous variable using data from the 2019 EMDHS, providing a more comprehensive understanding of how proximal and distal factors influence childhood linear growth.

In this study, child age was associated with a 0.02 unit decline in HAZ (β = -0.02), peaking around 30 months, consistent with evidence of growth faltering after infancy [19, 20]. This finding aligns with previous studies on Ethiopian children [21]. The negative association between child age and HAZ is well-established, reflecting increased vulnerability to stunting as children grow older, particularly after infancy. Consistent with the 2019 EMDHS analysis by Raru et al., the child's sex was not significantly associated with HAZ [22]. However, other studies [23–25] have reported higher stunting rates among male children, possibly due to higher birth weight and increased hunger sensitivity [25]. Moreover, an Ethiopian study found that male children are less likely to receive early and exclusive breastfeeding [26], highlighting the need for further investigation into potential gender-based differences in child nutrition and feeding practices.

Maternal education emerged as a key determinant of child growth. Each additional year of schooling was associated with a 0.036 unit increase in HAZ ($\beta = 0.036$, 95%CI: 0.009, 0.062, $p = 0.008$), consistent with findings from other studies [27–29]. Educated mothers are more likely to adopt health-promoting behaviors and make informed decisions about child nutrition and healthcare. However, some studies have reported no significant association between maternal education and stunting [21, 22], suggesting that other contextual factors may modify this relationship. Maternal age was also positively associated with HAZ, with each additional year of maternal age linked to a 0.015 unit increase (β = 0.0.015, (95%CI: 0.003, 0.026, $p = 0.012$). This finding suggests that maternal maturity and experience contribute to better child-rearing practices and nutritional outcomes.

Living in the capital, Addis Ababa, was significantly associated with higher HAZ scores ($\beta = 0.388$, 95% CI0.093, 0.683, $p = 0.01$), consistent with evidence of regional and economic disparities in child nutrition [30]. Access to better healthcare services, improved living standards, and greater exposure to health information in urban settings likely explain this association. Altitude above sea level also showed a significant negative association with HAZ, with a 1000-meter increase in altitude linked to a 0.21 unit decrease in HAZ ($\beta = -0.21$, 95%CI 0.34–0.07, $p = 0.003$). This finding aligns with Baye et al.'s study, which reported a 0.163 unit decrease in HAZ per 1000-meter increase in altitude across 133 countries [31]. Another study from Ethiopia also reported that living above 2500 m increases the odds of stunting by 41% compared to living below 1000 m [32]. Reduced oxygen availability, limited dietary diversity, and harsh environmental conditions at higher altitudes may contribute to impaired child growth.

The study has limitations. The cross-sectional design restricts causal inferences. Self-reported data may introduce recall and reporting bias, particularly for maternal age at first birth, dietary practices, and breastfeeding. The secondary analysis was based on the KR dataset from the 2019 EMDHS, which, as a mini-DHS, has a smaller sample size and fewer variables than a full DHS. High levels of missing data for variables such as vaccination, vitamin supplementary, ANC visits and counseling during pregnancy limited the ability to assess their association with child growth. To simplify analysis, all categorical variables were merged into binary categories which may have reduced the precision of estimates. Future research should use longitudinal designs to establish causal relationships between the identified predictors and child growth. Studies should also consider using unmerged categories to enhance the specificity of analysis and examine gender-specific patterns in growth and nutrition outcomes.

Conclusion

This study highlights the multifactorial determinants of linear growth faltering in Ethiopian children, with child age (β = -0.02/month), maternal education (β = +0.036/year), maternal age (β = +0.015 units/year), altitude (β = -0.21/kilometer), and capital city residence (β = + 0.388) emerging as significant drivers of HAZ variation in Ethiopian children aged 0–59 months. Our multilevel analysis reveals that independent variables account for an 18.06% reduction in cluster-level variance across 305 enumeration areas, underscoring the role of proximal and distal influences. Targeted interventions addressing these determinants, particularly improving maternal education are crucial for improving HAZ. Future research should build on these findings to develop comprehensive strategies for tackling linear growth faltering and improving child health outcomes.

Abbreviations

AIC	Akaike Information Criterion
ANC	Antenatal Care
BIC	Bayesian Information Criterion
CSA	Central Statistical Agency
EMDHS	Ethiopian Mini Demographic and Health Survey
HAZ	Height-for-age z score
ICC	Intra-class correlation coefficient
VIF	Variance inflation factor
WHO	World Health Organization
SD	Standard deviation

Supplementary Information

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Supplementary Material 1

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Author contributions

N.A. designed the study, carried out the analysis and wrote the manuscript.

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Data availability

The dataset used in this study is available from: https://www.dhsprogram.com/data/dataset/Ethiopia_Interim-DHS_2019.cfm and all Stata code used for the statistical analyses is available under "haz_code.do" on GitHub at: https://github.com/NebyuDanielAmaha/HAZ.

Declarations

Ethics approval and consent to participate

This is a secondary data analysis and ethical approval is not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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