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Generalized structural equation modeling of direct and indirect determinants of chronic undernutrition among under-five children in Ethiopia: further analysis of the 2019 mini Ethiopian demographic and health survey

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Abstract

Background Despite the global efforts and target to improve child nutrition and eliminate all forms of malnutrition by 2030, chronic undernutrition among under-five children is a major public health challenge in Ethiopia and it was 38%. The evidence of direct and indirect determinants based on the United Nations International Children's Emergency Fund (UNICEF) conceptual framework is limited. Therefore, this study aimed to determine the direct, indirect, and total effects of determinants on chronic undernutrition among under-five children in Ethiopia.

Method The study used the nationally representative weighted samples of 4,917 under-five children from the 2019 rounds of the DHS. A generalized structural equation model was used to determine the direct, indirect, and total effects of determinants on chronic undernutrition. The level of statistical significance was set at a p-value of less than 0.05.

Result The results indicated that children whose mothers had education have a 14% low odds of chronic undernutrition (AOR = 0.96, 95% CI; 0.7, 0.99). Those in urban residences had a 20% lower odds (AOR = 0.8, 95% CI; 0.49, 0.89), and children from better wealth index had a 10% lower odds (AOR = 0.9, 95% CI; 0.63, 0.98) of chronic undernutrition. In contrast, children with deprived living standards 2.7 (AOR = 2.7, 95% CI; 2.3, 3.1), and those with inadequate minimum dietary diversity (MDD) 1.69 (AOR = 1.69, 95% CI; 1.27, 2.3) times more likely to experience chronic undernutrition. Living standards through inadequate MDD (AOR = 1.04, 95% CI; 1.001, 1.25, residence through inadequate MDD (AOR = 1.04, 95% CI; 1.006, 1.1), wealth index via inadequate MDD (AOR = 1.01, 95% CI; 1.005, 1.02), and maternal education through antenatal care (ANC) (AOR = 0.88, 95%CI; 0.67, 0.99) had indirect effects on chronic undernutrition.

Conclusion The study found out determinants like maternal education, urban residence, and better wealth index were directly reducing the likelihood of chronic undernutrition. Conversely, deprived living standards and inadequate MDD directly raised the odds of chronic undernutrition. Determinants such as deprived living standards, residence, wealth index, and maternal education indirectly affected chronic undernutrition through inadequate MDD and ANC. Therefore, the finding suggests that interventions should adopt a holistic approach that includes maternal education,

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wealth index, living standard, dietary diversity, and ANC for reducing chronic undernutrition among under-five children in Ethiopia.

Keywords Generalized structural equation modeling, Direct and indirect determinants, Chronic undernutrition, Children, Ethiopia

Introduction

Chronic undernutrition is a chronic malnutrition condition where a child consistently does not receive enough essential nutrients over an extended period [1, 2].

Chronic undernutrition is characterized by low height-for-age and can have significant and lasting impacts on both physical and mental development, especially during early childhood [2, 3]. Children who experience chronic undernutrition may have stunted growth, delayed motor skills, and cognitive deficits that can impact their ability to learn and thrive later in life [4, 5].

Despite the global efforts to improve child nutrition and the Sustainable Development Goal (SDG) target 2.2 to eliminate all forms of malnutrition by 2030 [6], malnutrition continues to be a major public health challenge worldwide and it is devastating in Africa [7]. The 2022 data indicated that worldwide, more than 20% of children under the age of 5 a total of 148.1 million children were suffering from chronic undernutrition, while 45 million children were impacted by acute undernutrition [8]. It is concerning that around 5.2 million children under the age of 5 died as a result of malnutrition-related complications, and almost half of these deaths were caused by chronic undernutrition itself [5]. By 2020, in Africa, two out of every five children under the age of 5 suffered from chronic undernutrition, and more than one-quarter experienced acute undernutrition [9].

Since 2008, the Ethiopian government has shown a strong dedication to tackling child undernutrition through the development of various programs, policies, and initiatives such as the National Nutrition Program (NNP-I and NNP-II), Nutrition-Sensitive Agriculture (NSA) policy, Seqota Declaration, National Nutrition Policy and Strategy, and the recently created Food-Based Dietary Guideline [10, 11]. However, despite these efforts, child undernutrition persists and it continues to be a significant public health concern in Ethiopia, surpassing the global trends. The most recent Ethiopian demographic and health survey (EDHS) highlights this fact, indicating that 38% of children under the age of 5 in Ethiopia are affected by chronic undernutrition [12]. This emphasizes the necessity for additional research to give us a thorough comprehension of the factors influencing child chronic undernutrition.

To effectively tackle the challenge of child undernutrition in Ethiopia, it is crucial to have a thorough grasp of its basic, underlying, and immediate determinants in the Ethiopian context [13]. The framework developed by UNICEF for developing countries outlines three categories of factors that contribute to undernutrition: basic, underlying, and immediate determinants [14]. Various studies carried out worldwide have shown that a child's dietary intake and history of illness are immediate factors contributing to undernutrition. [15–18]. Likewise, research conducted in a variety of developing nations, including Ethiopia, underscores the notable correlation between child undernutrition and underlying factors such as health service utilization, feeding and caregiving practices [19–26], and the overall condition of the household (including access to clean water, sanitation, and hygiene facilities) [19, 22, 27–29]. Furthermore, child undernutrition was influenced by basic factors like maternal education, media exposure, and household wealth [26, 30–34]. While previous research has offered valuable information on determinants of child malnutrition, there are still notable gaps in the literature, especially concerning the direct and indirect factors that contribute to child undernutrition (the effects of basic factors through underlying factors and immediate factors for children's chronic undernutrition). These factors are often neglected in existing studies on the use of UNICEF guidelines on factors that contribute to chronic undernutrition. Furthermore, there is a need for methodological improvements to more effectively capture the intricate and diverse nature of undernutrition determinants as outlined in the UNICEF conceptual framework [14] (Fig. 1).

In this study, we employed generalized structural equation modeling (GSEM) methods, based on the UNICEF conceptual framework, to examine the connections between chronic undernutrition and its determinants. Unlike traditional regression analysis, GSEM provides a more detailed insight into these connections by enabling the assessment of underlying variables based on the UNICEF conceptual framework and their direct and indirect impacts on undernutrition in the path.

The findings hold significant implications for stakeholders engaged in programs aimed at addressing both the underlying causes and direct effects of chronic undernutrition, as outlined in the UNICEF conceptual framework. Focusing on children under the age of five presents a valuable opportunity to address the long-term impact

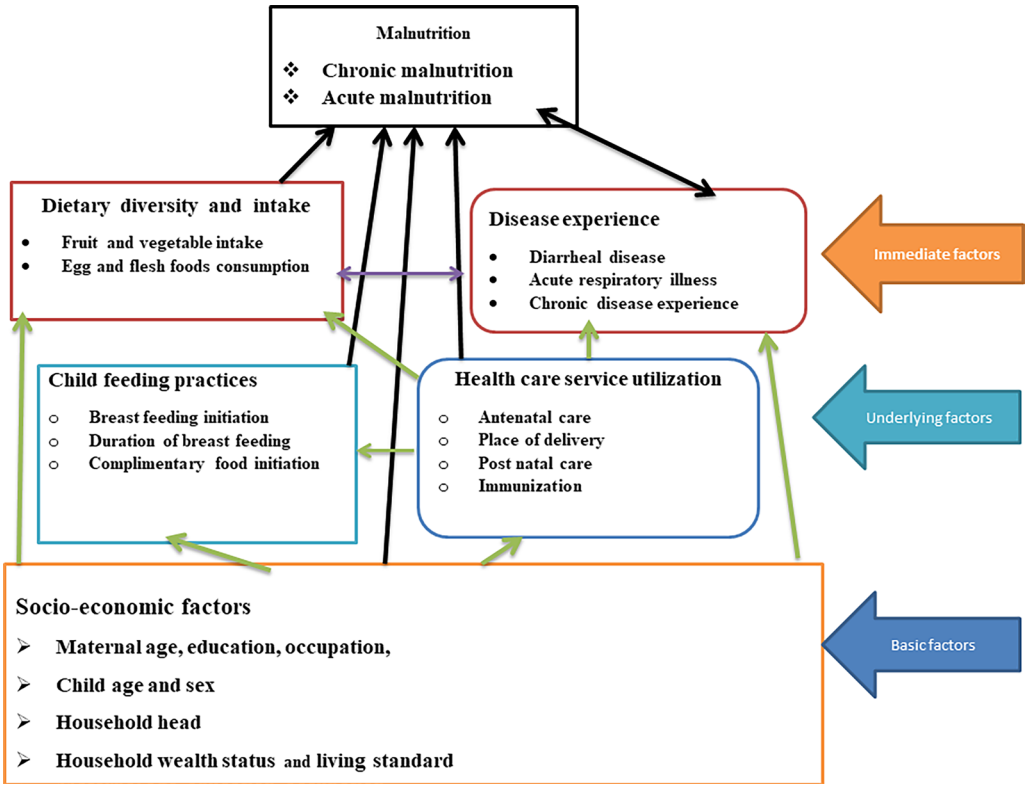

Fig. 1 Theoretical and conceptual relationships of determinants of malnutrition based on the UNICEF framework

of chronic undernutrition across generations. Therefore, this study aimed to comprehensively examine direct and indirect determinants of chronic undernutrition among under-five children in Ethiopia using generalized structural equation modeling.

Methods

Study design

A population-based cross-sectional study was used.

Study setting

The study was carried out in Ethiopia, which shares borders with Sudan to the west, Somalia and Djibouti to the east, Eritrea to the north, and Kenya to the south. Covering an area of 1,112,000 square kilometers, Ethiopia is divided into eleven regions and two municipal administrations. The country's landscape is characterized by an extensive high plateau that stretches across the Rift Valley, reaching into both the northwestern and southeastern highlands, each accompanied by their respective lowland areas. The topographical diversity is striking, with elevations ranging from 130 m below sea level in the Dallol depression of the Afar region to the summit of Mount Ras Dashen, which rises to 4,620 m above sea level in the Semien Mountains [35].

Population: The study population consisted of under-five children in the selected Enumeration Areas (EAs) in the survey conducted in Ethiopia in 2019.

Data source: The data for this study were obtained from the 2019 Ethiopian Demographic and Health Survey (EDHS) through the DHS Program website at https://dhsprogram.com/. Access was granted after contacting them via personal accounts and providing justification for the data request [36]. The dataset utilized was the birth record (BR), which encompasses the complete birth history of all interviewed women. Additionally, it included information on pregnancy and postnatal care, along with details on immunization, health, and nutrition, such as the dietary food groups of children born in the past 5 years [23, 24]. The DHS was a household survey carried out every 5 years in low and middle-income countries. The data gathered from the DHS survey was structured hierarchically, starting with households within clusters at the top level. The next tier comprises household members, followed by interviewed women and men as subsets of those members. At the lowest levels of the hierarchy are the pregnancies and children associated with each interviewed woman [23, 24].

Sample size and sampling method: The study utilized representative weighted samples of 4,917 children under

the age of five from the mini-EDHS. Participants were selected through a two-stage stratified sampling method. In the first stage, enumeration areas (EAs) were randomly selected, and in the second stage, households were randomly chosen from those areas.

Variable and variable measurement: The dependent variable of this study is chronic undernutrition which is categorized as "Yes" for those children with a height or length-for-age Z-score of less than -2 standard deviations (SDs) from the median value of the WHO Child Growth Standards for those aged 6 to 59 months and otherwise "No".

The independent variables for this study are based on the UNICEF conceptual framework, with adaptations made to suit the Ethiopian context. By reviewing relevant literature, key basic, underlying, and immediate factors have been identified and incorporated into the final model like; the age of the mother, father or child, sex of the household head, educational status of the mother, and partner working status of mother and father, wealth index, residence, preceding birth interval, number of under-five living children, household size and housing condition were used as the independent variable. For GSEM analysis and interpretation using STATA 17 software, several categorical variables such as education, vaccination status, and wealth index were converted into dummy categories.

Chronic undernutrition is characterized as children with a height or length-for-age Z-score of less than −2 standard deviations (SDs) from the median value of the WHO Child Growth Standards for those aged 6 to 59 months [37, 38].

The living standards of housing conditions are measured using the multidimensional poverty index (MPI) measurement criterion published by the UNDP's Human Development Report Office [39]. The measurement was based on the household living standards is deprived if the measured water source, types of toilet used, electricity, cooking material, house occupancy status, and assets were deprived. Water (households using water from an unimproved source such as open wells, open springs, or surface water deprived (1) and otherwise non-deprived (0)), sanitation/ toilet facilities (households using unimproved sanitation facilities such as pit latrines without slabs, open pit latrines, and hanging toilets deprived (1) and otherwise non-deprived (0)), electricity(if the household has no electricity, deprived (1), and otherwise non-deprived (0)), cooking fuel (if the household cooks using wood, charcoal, dung, deprived (1) otherwise non-deprived (0)), house occupancy status (if the household does not own a house, deprived (1), and otherwise non-deprived (0)), and assets (if the household does not own at least one of the following assets: radio, TV, mobile, tape recorder, or refrigerator, deprived (1) and otherwise non-deprived (0)).

Data management, processing, and analysis

The data utilized in this study were extracted, cleaned, coded, and analyzed using STATA version 17 statistical software. To ensure data consistency, exploratory data analysis was performed, including frequency and percentage calculations for categorical variables, as well as summary statistics for continuous variables to identify outliers and missing values. The data was then refined by categorizing it based on established research criteria, removing observations and incomplete variables, addressing outliers, and generating new variables. Necessary variable generation, recoding, and labeling were also performed. To adjust for the unequal probability of selection among the geographically defined strata and to account for non-responses, sample weights were applied. The complex sampling design was acknowledged using the SVY command in STATA to manage the clustering effects inherent in the sampling process. Finally, frequencies with percentages for categorical variables were computed to characterize the study population.

Generalized structural equation modeling

The study primarily employed Generalized Structural Equation Modeling (GSEM) to assess both the direct and indirect impacts of risk factors on chronic undernutrition in children. Given the hierarchical, complex, and interconnected nature of the determinants related to child undernutrition, a model capable of simultaneously incorporating and estimating multiple equations is essential [40]. This research utilized the Generalized Structural Equation Modeling (GSEM) which takes into account various levels (basic, underlying, immediate), with each level representing variables that influence one another and are treated as dependent or response variables, as illustrated in the conceptual framework with the binary outcome variable (Fig. 1). Generalized Structural Equation Modeling (GSEM) integrates statistical components from multiple regression, confirmatory factor analysis, and path analysis [41]. The analysis was conducted using STATA version 17 statistical software. This model facilitates the examination of intricate models that include both measured and unmeasured (latent) variables, thereby accommodating endogenous, exogenous, and mediator variables. Unlike path analysis, GSEM allows for the consideration of latent variables alongside observed ones. Mediation analysis was performed to evaluate the indirect effects of determinants on child undernutrition. Within the SEM framework, mediation can be classified as either full or partial [40]. Mediators may be categorized as single when only one

variable exists in the causal pathway between exogenous and endogenous variables, or as multiple when more than one mediator operates simultaneously at the same level in the structural model (referred to as "serial" or "sequential" mediation) [40, 42].

To determine the appropriate link functions for chronic undernutrition in GSEM, we initially considered the available Bernoulli distributions since the outcome variable has a binary category. We found that only three link functions-logit, probit, and complementary log–log—were viable options. To identify a suitable link function that would ensure the goodness-of-fit for binomial regression models, whether symmetric or asymmetric, to pinpoint determinants associated with child chronic undernutrition. The rationale for selecting a model was to evaluate the relative performance of the link functions and ascertain which one best fits the observed data. The most commonly used methods for model selection are the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). We applied the GSEM model using Bernoulli distribution with the logit link functions after a comparison of the models was performed using AIC and BIC. In the logit model, we estimated direct, indirect, and total effects. The indirect effects were calculated by multiplying the slope coefficients along each path, while the total effects were derived from the sum of direct and indirect effects. For instance, we can compute the indirect and total effects based on the following path diagram (Fig. 2). Both standardized and unstandardized coefficients, along with their exponential forms (odds ratios), were used to estimate the direct, indirect, and total effects of predictors on child chronic malnutrition (displayed in Fig. 3). The level of statistical significance was set at a p-value of less than 0.05.

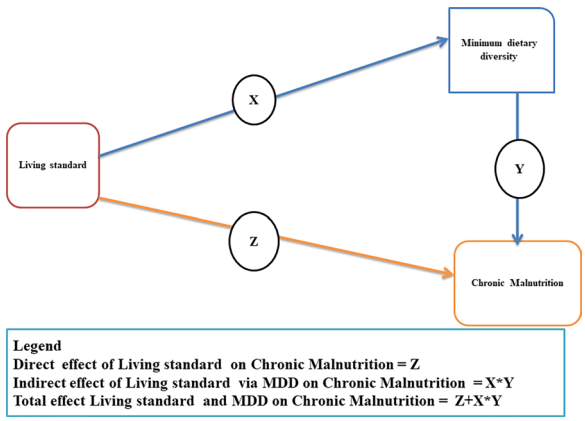

Fig. 2 The direct, indirect, and total effect of calculation of determinants on chronic undernutrition among under-five children in Ethiopia

Ethical approval: Ethical approval was not required for this study as we utilized the demographic and health survey (DHS), which anonymizes all data before public release. The DHS datasets used are publicly accessible. We obtained an authorization letter to download the DHS dataset from the Central Statistical Agency (CSA) after submitting a request at https://dhsprogram.com/. The dataset and all methodologies employed in this study were carried out following the principles outlined in the Declaration of Helsinki and alignment with DHS research guidelines.

Result

The Socio-demographic characteristics of the study population with chronic undernutrition

The study included a weighted sample of 4917 under-five children during the survey. The mean age and standard deviation of these women were 35 ± 7.5 respectively. The analysis of chronic undernutrition in the study population reveals significant correlations. Among maternal age groups, younger mothers (15–19 years) have a high undernutrition rate of 59.5%, while the 25–29 age group shows a low with 37.0%. Mothers with no education have a 41.7% undernutrition rate, which decreases to 16.4% among those with higher education. The poorest households showed a 42.7% undernutrition rate compared to just 22.9% in the richest households. The male-headed households demonstrate better nutritional outcomes (62.3% not undernourished) compared to female-headed ones (69.0% not undernourished). Urban residents have lower undernutrition rates (24.9%) compared to rural residents (40.7%). Families with two or fewer under-five children report a 36.4% undernutrition rate, while larger families (three or more children) face a slightly higher rate of 38.8% (Table 1).

Living standard or housing conditions of the study population with chronic undernutrition

Regarding housing conditions, cooking fuel and housing materials, significantly affect nutritional status and 37.5% of children experiencing chronic undernutrition were from deprived cooking fuel. Additionally, around 41.2% of this population resides in homes constructed with inadequate building materials, leading to poor living conditions that may compromise health and safety. The 40.3% chronic undernutrition rate is from the lack of electrical access and 38.1% of individuals with chronic undernutrition live in households with deprived toilet facilities. Furthermore, 37.7% of chronic undernutrition have inadequate water sources (Table 1).

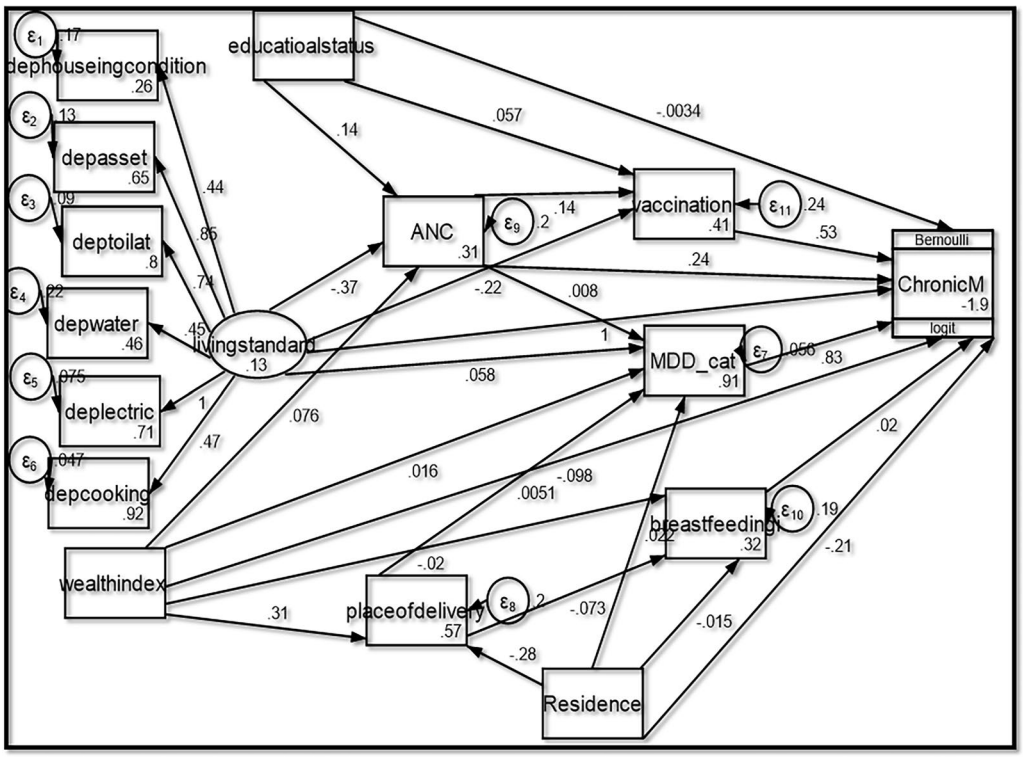

Fig. 3 A proposed generalized structural equation modeling and its hypothesized path diagram developed based on the existing body of knowledge. Circles in the GSEM diagram indicate latent exogenous and endogenous variables, whereas rectangles represent observed or measured exogenous and endogenous variables. Arrows between circles and rectangles indicate the paths and relationships between variables, as denoted by their coefficients. ANC, antenatal care; ZEGGFLESH: Zero egg and/or flesh food, zeroveorfrui: Zero vegetable and fruit; dep: deprived

The health service utilization of the study population with chronic undernutrition

The younger children aged 6–23 months, show a significant chronic undernutrition rate of 35.3%, with 514 out of 1,460 children affected. Antenatal care visits indicate that those with fewer than four visits have a higher chronic undernutrition rate of 34.3% (686 out of 2,000), compared to those with four or more visits, which have a rate of 34.0% (532 out of 1,562). In terms of breastfeeding practices, currently breastfeeding children have a lower chronic undernutrition rate of 32.1% (713 out of 2,232), while those who were ever breastfed face a higher rate of 41.3% (1,008 out of 2,443). Lastly, dietary diversity is crucial, as children with adequate dietary diversity show a chronic undernutrition rate of 28.0% (96 out of 344), compared to those with inadequate diversity, which has a much higher rate of 34.4% (905 out of 2,625) (Table 1).

Generalized structural equation modeling to determine direct, indirect, and total effects of determinants on chronic undernutrition

We applied the GSEM model using Bernoulli distribution with the logit link functions after a comparison of the models was performed using AIC and BIC (Table 2). The analysis was performed using generalized structural equation models (GSEM). The results indicated that children whose mothers have an education experienced a 14% reduction in the likelihood of chronic undernutrition (Adjusted odds ratio (AOR) = 0.96, 95% confidence intervals (CI); 0.7, 0.99). Those living in urban areas had a 20% lower risk (AOR = 0.8, 95% CI; 0.49, 0.89), and children from families with a better wealth index had a 10% lower risk (AOR = 0.9, 95% CI; 0.63, 0.98) of chronic undernutrition. In contrast, children from deprived living conditions were found to be 2.7 times more likely (AOR = 2.7, 95% CI; 2.3, 3.1) to experience chronic undernutrition, while those with inadequate MDD had a 1.69 times higher risk (AOR = 1.69, 95% CI; 1.27, 2.3) of chronic undernutrition (Table 3).

Furthermore, the analysis revealed indirect effects on chronic undernutrition: deprived living standards through inadequate MDD (AOR = 1.04, 95% CI; 1.001, 1.246), residence through inadequate MDD (AOR = 1.04, 95% CI; 1.006, 1.1), wealth index through inadequate MDD (AOR = 1.01, 95% CI; 1.005, 1.02), maternal education through antenatal care (AOR = 0.88,95%CI0.67,0.99) and deprived living standards through vaccination (AOR = 1.2, 95% CI; 1.10, 1.80). The total effects with

Table 1 The descriptive analysis of chronic undernutrition and characteristics of the study population

Variable	Category	Chronic undernutrition		Total
		No	Yes	
Maternal age	15–19	144	71	215
	20–24	582	324	906
	25–29	986	579	1565
	30–34	659	434	1093
	35–39	460	278	738
	40–44	222	95	317
	45–49	58	25	83
Educational status	No education	1539	1098	2,637
	Primary	1,127	613	1,739
	Secondary	297	67	363
	Higher	148	29	177
Wealth status	Poorest	650	485	1134
	Poorer	652	433	1085
	Middle	543	384	926
	Richer	567	299	866
	Richest	699	207	905
Sex of household head	Male	2,674	1,610	4,284
	Female	437	196	633
Residence	Urban	923	305	1228
	Rural	2187	1501	3689
Number of under-five children	≤ 2	2,692	1,542	4,234
	≥ 3	418	265	683
Household member	≤ 6	1,967	1,105	3,072
	≥ 7	1,143	701	1,844
Types of cooking fuel	Not deprived	194	59	253
	Deprived	2917	1748	4664
House building material	Not deprived	2,391	1,305	3,696
	Deprived	719	501	1,221
Household has electricity	Not deprived	998	372	1,370
	Deprived	2,113	1,434	3,547
Types of toilet facility	Not deprived	526	215	741
	Deprived	2584	1592	4176
Lively hood asset	Not deprived	1,190	485	1,674
	Deprived	1,921	1,322	3,242
Source of water	Not deprived	1,662	937	2,599
	Deprived	1,448	870	2,318
Sex of child	Male	1,552	957	2,509
	Female	1,559	849	2,408
Age of child	≤ month	457	46	502
	6–23 month	946	514	1460
	24–59 month	1708	1247	2955
ANC visit	< 4	1,314	686	2,000
	≥ 4	1,030	532	1,562
Place of delivery	Home	1,513	1,000	2,513
	Health institution	1,597	806	2,403
Duration of breastfeeding	ever breastfed, not c	1,435	1,008	2,443
	never breastfed	157	85	242
	still breastfeeding	1,519	713	2,232
MDD	Adequate	248	96	344
	inadequate	1720	905	2625

Key: ANC: antenatal care, MDD: minimum dietary diversity

Table 2 Model comparison under different link functions of generalized structural equation models

Model	AIC	BIC
Bernoulli, Logit	44609.6	44954.99
Bernoulli, Probit	44609.81	44955.2
Bernoulli, Cloglog	44609.9	44955.63

Key: AIC: Akaike Information Criterion, BIC: Bayesian Information Criterion

Table 3 The direct effect of basic and underlying determinants of chronic undernutrition based on the UNICEF framework using the 2019 mini-EDHS data

Determinants	MDD AOR (95% CI)	chronic undernutrition AOR (95% CI
Educational status		
No education		Reference
Have education		0.96(0.7, 0.99)*
Residence		
Rural		Reference
Urban	1.02(0.988,1.057)	0.8(0.49,0.89)*
Living standard		
Non–deprived		Reference
Deprived	1.02(1.0012,1.04)*	2.7(2.3,3.1)*
Wealth index		
Poor		Reference
Non-poor	1.015(0.98,1.24)	0.907(0.63,0.98)*
ANC visit		
< 4		Reference
≥ 4	1.008(0.98,1.032)	1.27(0.92,1.75)
Place of delivery		
Home		
Health institution	1.005(0.98,1.032)	
Breast feeding		
No		Reference
Yes		1.02(0.75,1.39)
Ever had vaccinated		
No		Reference
Yes		1.69(1.27, 2.3)*
MDD		
Adequate		Reference
Inadequate		2.29(1.2,5.47)*

Key: ANC: antenatal care, AOR: adjusted odds ratio, CI: confidence interval, MDD: Minimum dietary diversity, * indicates significant at p-value < 0.05

95%CI for paths are: deprived living standards—> inadequate MDD: AOR, 2.81 (2.30, 3.88), urban residence—> inadequate MDD (AOR = 0.83,95% CI; 0.49, 0.98), wealth index—> inadequate MDD (AOR = 0.91,95% CI; 0.63, 1.00), maternal education—> ANC (AOR = 0.85,95% CI; 0.47, 0.98), residence through breastfeeding to chronic undernutrition (AOR = 0.74,95% CI; 0.42, 0.87), maternal education through vaccination to chronic undernutrition (AOR = 0.80,95% CI; 0.50, 0.98), ANC through vaccination to chronic undernutrition (AOR = 0.73,95% CI; 0.44, 0.98), living standards through vaccination to undernutrition (AOR = 2.09,95% CI; (1.49, 2.79), living standards through ANC to chronic undernutrition (AOR = 2.17, 95% CI;1.56, 2.90) (Table 4).

The proportion of mediation on the path for the living standards through MDD to chronic undernutrition is approximately (37%), wealth index through MDD (11%), residence through breastfeeding (39%) while residence through MDD shows a proportion of 23%. Maternal education through ANC to chronic undernutrition reveals a proportion of approximately 22% and through vaccination, it is around 29%. Antenatal care through vaccination results in a proportion of about 47%. The living standards through vaccination show a proportion of 43%, and living standards through ANC indicate 55%.

Discussion

The generalized structural equation model was used to determine the direct, indirect, and total effects of determinants on chronic undernutrition based on the outlined UNICEF conceptual framework using the 2019 Min-Ethiopian Demographic and Health survey. The generalized structural equation models provide a means to assess the direct, indirect, and total effects of determinants on chronic undernutrition in children. The analysis revealed that determinants such as the mother's educational status, place of residence, living standards, wealth index, vaccination, and minimum dietary diversity (MDD) had a direct impact on chronic undernutrition. This finding is supported by other study findings [26, 33, 34, 37, 43, 44]. Additionally, the wealth index, place of residence, and living standards influenced chronic undernutrition indirectly through MDD, and living standards also affected chronic undernutrition indirectly through antenatal care (ANC). This finding is supported by other studies [26, 31, 34, 43, 44].

The study finding indicates that children from deprived living standards had a high odds of chronic undernutrition. The finding aligns with existing literature that highlights the significant impact of living standards factors on child nutrition. For example, research has demonstrated that families with poor living standards status often face barriers such as limited access to nutritious foods, poor hygiene of foods, and lack of knowledge and awareness [24, 45]. This highlights the need for comprehensive strategies that address both living standards and nutritional challenges to reduce chronic malnutrition among vulnerable populations.

The study finding indicates that the children whose mothers have an education experienced a reduction in the likelihood of chronic undernutrition. Similar to this finding another study supports that a mother's educational status can affect her ability to give the necessary care to her children [21, 27, 32]. As the level of education of mothers significantly increased, malnutrition decreased. This may be because an educated mother is more likely to learn proper feeding practices, improve hygiene, and gain improved access to knowledge and awareness. Those children living in urban areas had a lower risk of chronic undernutrition. This finding is in line with other previous studies [46–48].

The research finding indicates that children who come from families with deprived living standards are at a higher risk of experiencing chronic undernutrition. This

Table 4 The indirect and total effects of basic determinants on child chronic undernutrition through underlying and immediate determinants using the 2019 mini-EDHS data

The path to chronic undernutrition	Indirect effect AOR (95% CI)	Total effect AOR (95% CI
Living standards through MDD to malnutrition	1.04(1.001,1.25)*	2.81 (2.30, 3.88)*
Wealth index through MDD to malnutrition	1.01(1.005,1.02)*	0.91 (0.63, 1.00)*
Residence through breastfeeding to malnutrition	1.03(0.9,1.014)	0.74 (0.42, 0.87)*
Residence through MDD to malnutrition	1.02(1.006,1.1)*	0.83 (0.49, 0.98)*
Maternal education through ANC to malnutrition	1.033(0.99,1.1)	0.85 (0.47, 0.98)*
Maternal education through vaccination to malnutrition	1.029(0.98,1.08)	0.80 (0.50, 0.98)*
ANC through vaccination to malnutrition	1.07(0.92,1.16)	0.73 (0.44, 0.98)*
Living standards through vaccination to malnutrition	0.89(0.87,1.01)	2.09 (1.49, 2.79)*
Living standards through ANC to malnutrition	1.2(1.1, 1.8)*	2.17 (1.56, 2.9)*

Key: ANC: antenatal care, AOR: adjusted odds ratio, CI: confidence interval, MDD: Minimum MDD: minimum dietary diversity, * indicates significant at p-value < 0.05

finding is supported by other study findings in Ethiopia [31] and Kenya [49]. This underscores the importance of addressing the broader social determinants of health to improve nutrition outcomes for children living in living standards.

Children from families with a better wealth index had a lower risk of chronic undernutrition. This finding is in line with other previous studies [27, 50, 51]. Simply this may be because, families with higher wealth indices typically have better access to essential resources, including nutritious food, clean water, and healthcare services.

Children who experienced inadequate MDD had a higher risk of experiencing chronic undernutrition [47, 48]. This may be due to the lack of dietary diversity often results in insufficient intake of essential nutrients, vitamins, and minerals. Children require a variety of foods to meet their nutritional needs for growth and development[48].

Furthermore, the analysis revealed indirect and total effects of basic determinants on chronic undernutrition through underlying and immediate determinants: rural residence had an indirect effect on chronic undernutrition, mediated by inadequate MDD. This finding indicates that living in rural areas may be linked to higher odds of chronic undernutrition since rural residents might not have access to or consume a diverse enough diet. It suggests that interventions aimed at increasing dietary diversity could be effective in mitigating the risk of chronic undernutrition among rural dwellers. This finding is supported by other study findings in Ethiopia [22, 43].

The finding showed that the household wealth index indirectly affected chronic undernutrition via inadequate MDD highlighting the importance of economic factors in determining nutritional outcomes through the lens of dietary diversity. While this aligns with much of the existing literature emphasizing the role of socioeconomic status in nutrition [46], it also raises important questions about the complexity of these relationships and the need for multi-faceted interventions that address food availability, and diversity [50] to combat chronic undernutrition.

This research finding suggests that deprived living standards experienced during ANC have indirect consequences on chronic undernutrition. This finding indicates that improving living standards during pregnancy could be crucial for preventing chronic undernutrition in children, [43, 44].

The total effect finding indicates that socioeconomic factors like living standard, maternal education, place of residence, and household wealth through immediate determinants like dietary diversity, all have significant influences on the risk of chronic undernutrition among under-five children in Ethiopia. This finding points out that to address chronic undernutrition stepwise intervention is important. The mediation analysis points out that the living standards through MDD(37%), wealth index through MDD (11%), residence through breastfeeding (39%), residence through MDD (23%), maternal education through ANC (22%)and through vaccination (29%), ANC through vaccination (47%), the living standards through vaccination (43%), and living standards through ANC (55%) contributed for chronic undernutrition among under-five children in Ethiopia. The findings indicated that critical pathways through which various factors contribute to chronic undernutrition among under-five children in Ethiopia need holistic interventions. The significant contributions of living standards, maternal education, and residence highlight the need for comprehensive interventions that address not just nutritional aspects but also socioeconomic factors. Programs aimed at improving living conditions and economic stability could directly influence children's nutritional outcomes.

Practical and policy implications

The practical implication of the pathways finding such as the effect of living conditions, wealth, and maternal education through ANC visits, vaccination, and dietary diversity; underscores the need for an integrated, multisectoral approach to address child undernutrition. For example, the strong association between maternal education and access to antenatal care (ANC) and vaccination suggests that enhancing educational opportunities for women can have a cascading effect on service utilization like ANC and vaccination which in turn reduce children's chronic undernutrition. Educational programs should be prioritized to empower mothers with knowledge about nutrition, healthcare, and child-feeding practices. The impact of residence on breastfeeding practices indicates that geographical contexts play a significant role in infant feeding behaviors. Targeted breastfeeding promotion initiatives to improve breastfeeding rates, especially in rural areas are essential. Strengthening nutrition-sensitive programs: that address the underlying determinants of undernutrition, including the strengthening of initiatives related to poverty alleviation, women's empowerment on education, and improving living standards to improve MDD intern which can prevent chronic undernutrition.

Strength and limitation

The study utilized data from the 2019 MEDHS, which offers a nationally representative sample of children under five in Ethiopia. We employed the GSEM technique to evaluate the direct, indirect, and total effects of determinants on chronic undernutrition, grounded in

the UNICEF conceptual framework which enhances the study's strength. Although several key determinants were considered, some important variables were excluded from the analysis, such as disease status (including diarrheal diseases, acute respiratory illnesses, and chronic disease experiences), as these were not reported in the data. This may affect the estimate of chronic undernutrition through path analysis. Additionally, the study relied on self-reported information from survey respondents, which may be subjected to recall bias or social desirability bias, potentially impacting the accuracy of the findings.

Conclusion

The study findings highlight the complex, multifaceted nature of determinants contributing to chronic undernutrition in Ethiopian children. The generalized structural equation modeling comprehensively examines the direct and indirect determinants of chronic undernutrition among under-five children in Ethiopia. The study found that maternal education, living in urban areas, and a better wealth index were directly linked to reducing chronic undernutrition among children. Conversely, deprived living standards and inadequate MDD directly raised the odds of chronic undernutrition. The study revealed indirect pathways of determinants such as deprived living standards, residence, wealth index, and maternal education that affected chronic undernutrition through inadequate MDD and ANC visits. Therefore, the finding suggests that interventions should adopt a holistic and systems-level approach that includes maternal education, wealth index, living standard, dietary diversity, and ANC to accelerate progress in reducing chronic undernutrition among under-five children in Ethiopia.

Abbreviations

AIC	Akakian information Criteria
AOR	Adjusted odds ratio
ANC	Antenatal care
BIC	Bayesian information Criteria
CSA	Central statistical agency
DHS	Demographic and health survey
EA	Enumeration area
LMIC	Low and middle-income countries
MDD	Minimum dietary diversity
SSA	Sub-Saharan Africa
WHO	World hath organization

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Author contributions

AE contributed to the conception, design, data curation, investigation, analysis, interpretation of data, and drafting of the manuscript. AE, AK, TD, and YT contributed to reviewing editing, revising, giving final approval of the version to be published, and agreeing to be accountable for all aspects of the work.

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Availability of data and materials

Data are available in a public, open-access repository. Data for this study were sourced from Demographic and Health Surveys (DHS) and are available here: https://dhsprogram.com/.

Declarations

Ethics approval and consent to participate

No ethical approval was needed because we had used the demographic and health survey which identifies all data before making it public, and the used DHS data sets are openly accessible. An authorization letter was requested to download the DHS data set and this was obtained from the Central Statistical Agency (CSA) after being requested at https://dhsprogram.com/.The dataset and all methods of this study were conducted according to the guidelines laid down in the Declaration of Helsinki principles and based on DHS research guidelines.

Consent to publication

Not applicable.

Participant consent for publication

No consent to publish was needed for this study as we did not use any details, images, or videos related to individual participants. In addition, the data used are available in the public domain.

Competing interests

The authors declare that they have no competing interests.

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