Exploring the Reduction in Childhood Undernutrition in Morocco (2003–2018): Insights From a Decomposition Analysis

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Abstract

Despite significant progress, childhood undernutrition remains a critical public health challenge in Morocco, impacting child development and well-being. This study examines the drivers behind the reduction in undernutrition between 2003 and 2018, employing multilevel logistic regression and Fairlie decomposition analysis to assess the influence of socioeconomic, demographic, and contextual factors. Using data from the 2003–2004 and 2018 National Survey on Population and Family Health (NSPFH), the findings underscore the pivotal roles of improved maternal education, enhanced child healthcare access, and better household living conditions, including access to clean water and sanitation. However, rural areas lag significantly behind their urban counterparts, highlighting persistent regional disparities that demand urgent attention. These results underline the critical need for targeted interventions to advance maternal education, strengthen healthcare infrastructure, and prioritize rural development. This study highlights past achievements by aligning with long-term development objectives and global health initiatives. It provides actionable insights to sustain and accelerate reductions in childhood undernutrition in Morocco.

Keywords

Children under five years; Fairlie decomposition; maternal education; multilevel logistic regression; regional disparities; undernutrition

Introduction

Undernutrition, a multifaceted condition, remains a critical global challenge despite significant efforts and political commitments. Its primary indicators—stunting, underweight, and wasting—reflect different aspects of nutritional deficiencies and contribute to nearly half of all deaths among children under five years old (U5). Recent global estimates reveal that 149 million children U5 suffer from stunting, 45 million from wasting, and 39 million are underweight (UNICEF et al., 2023). While significant progress has been made in reducing these indicators globally, mainly with stunting declining from 33.1% in 2000 to 22% in 2020 (World Health Organization [WHO], 2024), disparities persist. Sub-Saharan Africa and South Asia continue to bear the highest burden, and global targets, such as reducing stunting to below 15% by 2025, remain out of reach (Heidkamp et al., 2021).

While significant global progress has been made in reducing childhood undernutrition, Morocco provides a compelling example of success and ongoing challenges. Morocco has made substantial strides in reducing childhood undernutrition between 2003 and 2018, with the prevalence of undernutrition among children U5 dropping from 28.0% to 18.4%, a reduction of 9.6 percentage points (Berrouyne & Hami, 2024). This achievement is attributed primarily to targeted health interventions, maternal and child healthcare improvements, better sanitation, and broader socioeconomic development (Development Initiatives, 2020). Stunting rates in Morocco decreased from 18.1% to 15.1%, underweight prevalence declined from 10.2% to 2.9%, and wasting rates dropped from 9.3% to 2.6% over the same period (Ministry of Health [Morocco] et al., 2004; Ministry of Health [Morocco] & PAPFAM Project, 2019).

Morocco is a notable example of remarkable progress and persistent challenges in reducing childhood undernutrition. Between 2003 and 2018, the prevalence of undernutrition among children U5 dropped from 28.0% to 18.4%, a reduction of 9.6 percentage points (Berrouyne & Hami, 2024). This achievement is attributed primarily to targeted health interventions, maternal and child healthcare improvements, better sanitation, and broader socioeconomic development (Development Initiatives, 2020). Stunting rates in Morocco decreased from 18.1% to 15.1%, underweight prevalence declined from 10.2% to 2.9%, and wasting rates dropped from 9.3% to 2.6% over the same period (Ministry of Health [Morocco] et al., 2004; Ministry of Health [Morocco] & PAPFAM Project, 2019).

However, significant disparities remain, particularly among vulnerable groups. Rural children (23.6%) and those from the poorest households (29.1%) continue to bear the highest burden of stunting, highlighting the persistent inequalities in access to nutrition and healthcare services. Addressing these disparities is crucial to sustaining Morocco's progress and ensuring the country meets global nutrition targets.

Key drivers of the global reduction in undernutrition include expanded maternal and child health services, improved access to antenatal care, immunization, and breastfeeding promotion (Bhutta et al., 2013). Additionally, research has shown that maternal and child undernutrition remains a significant issue in low-income and middle-income countries, with undernutrition and overweight coexisting as public health challenges. This dual burden requires comprehensive intervention strategies across sectors to address both forms of malnutrition (Black et al., 2013).

Building on prior research, including Berrouyne et al. (2024), this study investigates the factors contributing to the reduction of childhood undernutrition in Morocco between 2003 and 2018. Previous analyses have highlighted the critical role of maternal education, socioeconomic status, and access to basic infrastructure in improving child nutrition outcomes. However, persistent disparities remain, particularly in rural areas and among poorer households. To address these gaps, this study employs a Fairlie decomposition analysis to quantify the contributions of socioeconomic and demographic factors to the observed changes in undernutrition prevalence. By complementing the findings of Berrouyne et al. (2024), this analysis provides a deeper understanding of the progress achieved and the challenges that persist. It aligns with global frameworks such as the 2025 World Health Assembly targets and the 2030 Sustainable Development Goals. It offers actionable insights for policymakers aiming to sustain and accelerate reductions in childhood undernutrition.

The analysis is structured around three primary considerations:

i) Global nutritional efforts have contributed to considerable progress, offering valuable insights for adjusting national policies and interventions.

ii) Research consistently demonstrates a strong link between reductions in undernutrition and improvements in family wealth, parental education, and access to sanitation services.

iii) Recognizing the gaps in data for children U5, this study adopts a comprehensive approach by analyzing family, community, and household factors.

Data from the 2003–2004 and 2018 National Survey on Population and Family Health (NSPFH) will be combined into a single, unified dataset, retaining consistent variables across both years to ensure comparability. This combined dataset will explore how socioeconomic status, parental education, access to healthcare, sanitation, and community environments influence child undernutrition outcomes in Morocco.

In addition, this study will quantify how socioeconomic and demographic changes have contributed to the reduction in stunting over time, using a Fairlie decomposition analysis (Fairlie, 2005). This approach will allow for a deeper understanding of the specific factors that have driven the observed improvements in child nutrition. The insights generated from this study will help policymakers refine strategies to sustain and accelerate progress in reducing childhood undernutrition while addressing persistent inequalities that disproportionately affect vulnerable groups in Morocco.

Methodology

Data sources

This study draws on data from the National Survey on Population and Family Health (NSPFH) conducted in 2003 and 2018 by the Ministry of Health [Morocco] et al. (2004) and the Ministry of Health [Morocco] and PAPFAM Project (2019). These nationally representative surveys also ensure representativity at the regional level and provide detailed insights into fertility, mortality, health, and nutrition, including critical indicators of child undernutrition.

- **Survey Design:** Both surveys used a two-stage sampling method, targeting 12,000 households in 2003–2004 and 15,300 households in 2018.
- **Participants:** In 2003–2004, 16,000 women aged 15-49 were interviewed, and 9,969 were interviewed in 2018.
- **Focus on Children U5:** Key indicators such as stunting, wasting, and underweight were collected for children under five years (U5) to assess their nutritional status and monitor health policy impacts.

The effective sample sizes for this study were 5,311 children in 2003–2004 and 5,983 children in 2018, after accounting for missing or incomplete data.

Inclusion criteria

The inclusion criteria ensured consistency and comparability across the two surveys. Children under five years (U5) were included based on the availability of complete data for the following variables:

- **Complete anthropometric data:** Height, weight, age, and sex, enabling the calculation of z-scores for stunting, wasting, and underweight.
- **Socio-economic Data:** Information on parental education, household wealth, and community characteristics.

Children with incomplete or implausible anthropometric measurements (e.g., z-scores outside WHO thresholds) were excluded from the analysis.

Variables

Dependent variable

Undernutrition, measured using three indicators (stunting, wasting, underweight) based on the World Health Organization (WHO) (2006) Child Growth Standards.

Explanatory variable

The explanatory variables include various individual, household, socioeconomic, and demographic factors that have been shown to influence undernutrition status among children U5. These variables were categorized into five sections for analysis: i) child characteristics, ii) mother characteristics, iii) father characteristics, iv) household characteristics, and v) contextual characteristics.

Child's characteristics

The child's age group was divided into six categories: 1 = less than 6 months, 2 = 6–11 months, 3 = 12–23 months, 4 = 24–35 months, 5 = 36–47 months, and 6 = 48–59 months. The child's sex was recoded as 1 = male and 2 = female. Birth order was recoded as 1 = firstborn, 2 = second or third child, and 3 = fourth child or more.

Couple's education

The couple's education variable includes five categories: households where both parents have no education (Code 0), households where both parents have completed primary education (code 1), and households where both parents have attained secondary education or higher (Code 2). The variable accounts for educational imbalances, with households where the mother is more educated than the father (Code 3) and those where the mother is less educated than the father (Code 4). This categorization captures the combined and relative educational background of parents, reflecting how these differences may influence household decision-making, access to information, and health-seeking behaviors.

Mother's characteristics

The mother's educational status was recoded as 0 = no education, 1 = primary education, and 2 = secondary or higher education. The mother's age was categorized into five groups: 1 = under 25 years, 2 = 25–29 years, 3 = 30–34 years, 4 = 35–39 years, and 5 = 40 years or over.

Father's characteristics

The father's educational status was recoded as 0 = no education, 1 = primary education, and 2 = secondary or higher education.

Household characteristics

A household head's age was divided into five categories: 1 for those under 25 years old, 2 for those between 25 and 29 years old, 3 for those between 30 and 34 years old, 4 for those between 35 and 39 years old, and 5 for those above 40 years old. Access to clean water was recoded as 0 = no (lack of access to clean water) and 1 = yes (access to clean water). Sanitation facilities were categorized as 0 = no (unimproved facilities) and 1 = yes (improved sanitation). Household size was divided into three groups: 1 = small (2–3 members), 2 = medium (4–6 members), and 3 = large (7 or more members). The wealth index was classified into three categories: 1 = poor, 2 = middle, and 3 = rich, based on asset ownership and household characteristics, using principal component analysis.

Contextual characteristics

Three contextual (community-level) factors were included in the analysis:

The area of residence was recoded as 1 = urban and 2 = rural. The percentage of poor people in the community was categorized as 0 = low and 1 = high, reflecting the concentration of poverty within the community. The percentage of educated women in the community was categorized as 0 = low, 1 = high, and 2 = very high, capturing the level of female education within the community, which can have broader implications for child nutrition outcomes.

Statistical analysis

A bivariate analysis was initially performed to examine the sample's characteristics and the differences in undernutrition prevalence between 2003 and 2018. This analysis allowed for exploring fundamental relationships between the study variables, including the trends in undernutrition rates over time. A proportion test was applied to assess the statistical

significance of changes in undernutrition prevalence.

For the proportion test, we compared the prevalence of undernutrition across the two periods. The test statistic for a single proportion is calculated as (Roldán-Nofuentes et al., 2024):

$$Z = \frac{\hat{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} \quad (1)$$

Where $\hat{p}$ is the observed proportion in the sample, p_0 is the hypothesized proportion, and n represents the sample size. For comparing the prevalence between the two years, the two-proportion Z-test was used, which is expressed as:

$$Z = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \quad (2)$$

Where $\hat{p}_1$ and $\hat{p}_2$ are the observed proportions in 2003 and 2018, respectively, and $\hat{p}$ are the pooled sample proportions across both years. This method helped determine whether the observed changes in stunting rates were statistically significant or could be attributed to random variation.

Bivariate analysis explored the sample characteristics and differences in undernutrition prevalence between 2003 and 2018. A proportion test assessed the statistical significance of changes in undernutrition prevalence over time. A multilevel logistic regression model was utilized to investigate the factors contributing to stunting among children under the age of 5. This approach accounts for the hierarchical structure of the data, capturing variations at the individual, household, and community levels. The multilevel model provides a nuanced and comprehensive analysis by considering both individual-level determinants and broader contextual factors.

Econometric specification

Following the proportion test, we applied a multilevel logistic regression model to investigate the factors associated with childhood undernutrition. Given the hierarchical structure of the data, with observations clustered at the individual, household, and community levels, this model allowed us to account for potential within-group correlations (Snijders & Bosker, 1999). The hierarchical structure of the data and the presence of a binary dependent variable imply potential correlations within the same level of observations. However, most single-level analysis models assume independence, which can be limited due to this correlation. To address this, we applied a multilevel model to analyze the effects of independent variables on childhood stunting across individual, household, and contextual levels.

The intraclass correlation coefficient (ICC) is a key statistic generated by the null model (M_0). If this coefficient significantly differs from zero, it indicates that multiple unobserved factors affect child malnutrition rates within the same household or community. The larger the variance, the greater the disparity between categories. The null model can be represented as follows:

$$logit(Y_{ijk}) = log\, P\left((Y_{ijk} = 1)/(1 - P(Y_{ijk} = 1)\right) = b_0 + z_k + t_{jk} + u_{ijk} \quad (3)$$

In this context, *i* represents observations at the individual level, *j* at the household level, and

k at the community level. Where Y_{ijk} represents the three-level stunting of the child in this model. Specifically, the expression $b_0 + z_k + t_{jk} + u_{ijk}$ stands for both the fixed and random parts of the model. The unobserved random variables are not observed but are normally distributed with variances σ_z^2, σ_t^2, and $\pi^2/3$, respectively, and a mean of 0. After that, all explanatory variables are included in the full model (M_1). As a result, how we represent the complete model (M_1) is as follows:

$$logit(Y_{ijk}) = b_0 + b_1\, x_{ijk} + b_2\, x_{jk} + b_3\, x_k + z_k + t_{jk} + u_{ijk} \quad (4)$$

Having established the econometric specification of our multilevel model to account for the hierarchical data structure and unobserved factors, we next aimed to understand the changes in undernutrition prevalence between 2003 and 2018. To achieve this, the Fairlie decomposition technique was applied. Initially, bivariate analysis illustrated the crude differences in stunting rates across the two time periods. The Fairlie decomposition method (Fairlie, 2005), an extension of the Blinder-Oaxaca decomposition (Blinder, 1973; Oaxaca, 1973) for binary outcomes, was then used to identify and quantify the contributions of various socioeconomic, demographic, and household factors to the observed changes in undernutrition prevalence. The approach relies on the following equation, which assumes a non-linear dependent variable (in our case, undernutrition):

$$Y^{t1} - Y^{t2} = \left[\sum_{i=1}^{N^{t1}} \frac{F\left(X_i^{t1}\,\beta^{t2}\right)}{N^{t1}} - \sum_{i=1}^{N^{t2}} \frac{F\left(X_i^{t2}\,\beta^{t2}\right)}{N^{t2}}\right] + \left[\sum_{i=1}^{N^{t1}} \frac{F\left(X_i^{t1}\,\beta^{t1}\right)}{N^{t1}} - \sum_{i=1}^{N^{t1}} \frac{F\left(X_i^{t1}\,\beta^{t2}\right)}{N^{t1}}\right] \quad (5)$$

Where Y represents the dependent variable (undernutrition) at two different time points, $t1$ (2003-2004) and $t2$ (2018). For each time point, N^t denotes the sample size, X^t is a row vector containing the average values of the independent variables, and β^t is the corresponding vector of coefficient estimates.

The first term on the right side of the equation accounts for compositional changes due to differences in characteristics, often called the 'explained' portion of the model. The second term represents coefficient changes, which are attributed to the 'unexplained' portion. We will, however, limit our discussion to the explained portion of the aggregation and the individual contributions of each covariate. Applying the decomposition method to categorical explanatory variables, particularly those without an inherent order from low to high, presents a challenge known as the 'identification problem.' The estimates produced by the decomposition can vary based on the selected reference (omitted) category in the model, which cannot be resolved by a single equation.

By combining multilevel logistic regression and the Fairlie decomposition technique, this study provides a detailed and robust understanding of the drivers behind the reduction in undernutrition. The multilevel approach accounts for the hierarchical nature of the data, while the decomposition method quantifies the relative contributions of individual, household, and community factors to changes in stunting rates. This comprehensive analysis offers critical insights for policymakers seeking to further reduce childhood undernutrition and address persistent inequalities in Morocco.

The data analysis for this study was conducted using Stata software, Version 17 (StataCorp.

2023).

Results

Changes in undernutrition outcomes

The bivariate analysis presented in Table 1 demonstrates significant progress in reducing the prevalence of undernutrition among children U5 in Morocco between 2003 and 2018. Overall, the total prevalence of undernutrition declined by 9.6% (p = .000), reflecting substantial improvements over the 15-year period. Despite these gains, persistent disparities across socioeconomic and regional lines indicate that targeted interventions in vulnerable populations remain essential to further reductions in childhood undernutrition.

At the individual level, the proportion test reveals considerable progress across various demographic and household factors. Notably, undernutrition among children aged 12–23 and 24–35 months declined by 10.2% and 10.7%, respectively (p = .000), underscoring the importance of nutritional interventions during these critical early years. Gender differences also emerged, with female children experiencing a more substantial reduction in undernutrition (-13.3%, p = .000) compared to their male counterparts (-6.2%, p = .000). This suggests that nutritional programs may have been more effective for girls during this period. Parental education also proved to be a pivotal factor in the reduction of undernutrition. Households where both parents lacked formal education showed a marked decline in undernutrition (-9.4%, p = .000), highlighting those interventions focused on the most vulnerable groups. However, the effect of parental education diminished in households with higher education levels, suggesting that these households were not the primary focus of recent nutritional interventions. Among mothers, those with no formal education saw the most significant reductions in undernutrition (-8.1%, p = .000), as did mothers aged 30–34 years (-10.6%, p = .000), demonstrating the impact of maternal education and age on child nutrition outcomes.

At the household level, access to clean water and improved sanitation were strongly correlated with reductions in undernutrition. Clean water access led to a 6.4% reduction (p = .000), while improved sanitation contributed to a 7.2% reduction (p = .000). These findings underscore the importance of infrastructure improvements in combating undernutrition, particularly in rural areas. Indeed, rural regions experienced a more significant decline in undernutrition (-11.0%, p = .000) compared to urban areas (-7.9%, p = .016), highlighting the effectiveness of rural-focused interventions.

Community-level factors further influenced the outcomes. Regions with lower poverty rates saw a notable decrease in undernutrition (-12.8%, p = .000), suggesting that economic improvements are crucial in reducing childhood malnutrition. Conversely, areas with a higher proportion of educated women saw more modest improvements (-3.6%, p = .380), indicating the continued need for educational outreach in these communities.

In summary, while Morocco has made marked progress in reducing childhood undernutrition over the past 15 years, the persistence of socioeconomic and regional disparities underscores the need for continued, targeted interventions to ensure that the most vulnerable populations benefit equally from these gains.

Table 1: Prevalence of Undernutrition Among Children Aged Under Five Years by Characteristics in Morocco

Characteristic	2003	2018	Difference	*p* value
Age of child				
Under 6 months	19.9	18.8	-1.1	.736
6–11 months	25.6	18.7	-6.9	.002
12–23 months	29.9	19.7	-10.2	.000
24–35 months	32.9	22.2	-10.7	.000
36–47 months	29.1	17.7	-11.4	.000
48–59 months	25.4	13.9	-11.5	.000
Sex of child				
Male	26.7	20.5	-6.2	.000
Female	29.4	16.1	-13.3	.000
Child rank				
1	23.9	16.4	-7.5	.000
2–3	28.5	17.2	-11.3	.000
4 or over	31.3	22.5	-8.8	.000
Parents education level				
Both parents without education	34.5	25.1	-9.4	.000
Both parents with primary education	23.5	21.5	-2.0	.358
Both parents with secondary or higher education	19.1	14.1	-5.0	.195
Mother more educated than father	22.6	15.8	-6.8	.000
Mother less educated than father	26.0	17.5	-8.5	.000
Maternal education				
No education	32.8	24.7	-8.1	.000
Primary	22.7	15.3	-7.4	.000
Secondary or higher	16.1	12.7	-3.4	.044
Maternal age				
< 25 years	27.7	20.2	-7.5	.056
25–29 years	27.6	17.7	-9.9	.000
30–34 years	27.5	16.9	-10.6	.000
35–39 years	29.3	19.5	-9.8	.000
40 years or over	28.3	18.5	-9.8	.000
Paternal education				
No education	32.3	22.1	-10.2	.000
Primary	26.2	18.5	-7.7	.000
Secondary or higher	21.2	13.7	-7.5	.000
HH age				
< 25 years	40.1	22.8	-17.3	.000
25–29 years	33.6	23.7	-9.9	.000
30–34 years	28.5	17.5	-11.0	.000
35–39 years	24.8	17.3	-7.5	.000
40 years or over	27.8	18.4	-9.4	.000
Clean water				
No	37.0	27.1	-9.9	.000
Yes	24.2	17.8	-6.4	.000
Clean water closet				
No	39.0	35.2	-3.8	.134
Yes	24.7	17.5	-7.2	.000
Household size				
Small (2–3 members)	22.1	15	-7.1	.000
Medium (4–6 members)	27.1	18.1	-9.0	.000
Large (7 members or over)	29.9	21.9	-8.0	.000

Characteristic	2003	2018	Difference	*p* value
Household wealth quintile				
Poor	36.0	22.8	-13.2	.000
Middle	25.5	18.5	-7.0	.000
Rich	18.6	12.1	-6.5	.000
Place of residence				
Urban	21.1	13.2	-7.9	.016
Rural	35.3	24.3	-11.0	.000
Percentage of poor in community				
Low	26.2	13.4	-12.8	.000
High	29.2	24.0	-5.2	.000
% of educated women in community				
Low	32.1	23.2	-8.9	.000
High	20.4	17.7	-2.7	.245
Very high	17.7	14.1	-3.6	.380
Total	**28.0**	**18.4**	**-9.6**	**.000**

Note: Authors' conception

Multilevel logistic regression

The multilevel logistic regression results in Table 2 comprehensively analyze the factors influencing undernutrition among children U5 in Morocco. This model incorporates individual, household, and community-level variables, along with the survey years (2003 and 2018), offering critical insights into the key determinants of child undernutrition. The model reveals substantial variation at the community and household levels. The intra-class correlation (ICC) for the community level is significant at 9.3% (ICC = 0.093, p value < .001), indicating that community factors explain a considerable proportion of the variation in undernutrition. The variation is even more pronounced at the household level, with an ICC of 47.0% (ICC = 0.470, p < .001). These results underscore the importance of household and community environments in shaping nutritional outcomes. Moreover, the overall model, as confirmed by the Wald chi-square statistic (χ^2 = 416.8, p < .001), is highly significant, demonstrating that the individual, household, and community-level variables collectively provide a robust explanation for the variation in undernutrition among children U5.

Estimates from the multilevel logistic regression model indicate a statistically significant 26% reduction in the likelihood of undernutrition among children U5 in 2018 compared to 2004 (OR = 0.741, p < .001). This decline reflects the effectiveness of health interventions and broader socioeconomic improvements over the 15-year period. The model isolates the temporal effect by including the survey year as a variable, providing robust evidence of the impact of policy changes and nutrition-focused initiatives in reducing child undernutrition in Morocco. This finding underscores an overall improvement in child nutritional status linked to targeted interventions and long-term development efforts. At the individual level, a child's age is crucial in determining the likelihood of undernutrition. Children aged 12–23 months (OR = 1.715, p < .001), 24–35 months (OR = 2.025, p < .001), and 36–47 months (OR = 1.455, p < .001) show significantly higher odds of undernutrition compared to those aged 48–59 months. The odds increase as the child is younger, with the highest risk observed among children aged 24–35 months, highlighting the vulnerability of younger children to nutritional deficiencies during critical growth periods.

Parental education is an important determinant. Children of parents without education exhibit a significantly lower risk of undernutrition (OR = 0.423, p < .001) than those whose

parents have secondary or higher education, which seems contrary to expectations. Moreover, children whose mothers have lower educational attainment than their fathers are also at a lower risk of undernutrition (OR = 0.527, $p < .001$), indicating a lower likelihood of undernutrition than the reference group. Maternal education itself is a strong predictor. Children born to mothers with no education are over three times more likely to be undernourished (OR = 3.330, $p < .001$) compared to children whose mothers have secondary or higher education, highlighting the critical role maternal knowledge and empowerment play in child health outcomes. The results demonstrate that younger children, mainly those aged 12–35 months, are at heightened risk of undernutrition, while parental education, especially maternal education, is a crucial protective factor. Children of uneducated mothers face significantly higher odds of undernutrition, highlighting the vital role of maternal education and empowerment. Addressing these individual-level factors through targeted interventions is essential for improving child nutrition outcomes in Morocco.

At the household level, the socioeconomic conditions of the household further contribute to the risk of undernutrition. Children living in households without access to clean water (OR = 1.580, $p < .001$) or clean toilet facilities (OR = 1.694, $p < .001$) are significantly more likely to suffer from undernutrition. Furthermore, household size is positively associated with undernutrition; children from larger households, particularly those with seven or more members (OR = 1.454, $p < .01$), face an elevated risk compared to those from smaller households. Wealth also exerts a notable influence, with children from poor households (OR = 1.392, $p < .01$) and those from middle-income households (OR = 1.343, $p < .01$) being significantly more at risk of undernutrition compared to their peers from wealthier families. Another crucial factor at the household level is the age of the household head. Households headed by individuals under 25 years of age are at a significantly higher risk of having undernourished children (OR = 2.217, $p < .01$) compared to those headed by individuals aged 40 years or over. These findings indicate that economic deprivation, household composition, access to basic infrastructure, and the age of the household head are key determinants of child undernutrition at the household level in Morocco. Addressing these household factors through comprehensive, targeted interventions is essential for improving child nutrition outcomes nationwide.

The contextual factors from the multilevel logistic regression model reveal significant disparities in undernutrition among children U5 in Morocco. Children living in rural areas are more than twice as likely to be undernourished as their urban counterparts (OR = 2.308, $p < .001$), underscoring rural residency as a significant risk factor. Additionally, communities with a high percentage of poor households exhibit a markedly higher risk of undernutrition (OR = 4.843, $p < .001$), highlighting the profound impact of economic deprivation at the community level. Regarding the percentage of educated women in a community, the "high" category shows marginal significance at the 10% level (OR = 0.763, $p = .10$), suggesting that a higher proportion of educated women may have a protective effect, though it requires cautious interpretation. These results emphasize the crucial roles of place of residence and community-level poverty in determining child nutritional outcomes while indicating a potential, albeit weaker, influence on women's education at the community level.

Table 2: Multilevel Logistic Regression Estimates for Undernutrition Among Children Under Five by Characteristics in Morocco

Characteristic	OR	95% CI
Constant	0.018**	[0.010, 0.033]
INDIVIDUAL FACTOR		
Year		
2003	**Ref.**	
2018	0.741**	[0.606, 0.906]
Child age months		
48–59 months	**Ref.**	
Under 6 months	1.240ᵀ	[0.960, 1.601]
6–11 months	1.351*	[1.053, 1.733]
12–23 months	1.715***	[1.399, 2.102]
24–35 months	2.025***	[1.652, 2.483]
36–47 months	1.455***	[1.189, 1.779]
Sex of child		
Female	**Ref.**	
Male	1.073	[0.945, 1.219]
Child rank		
4 or over	**Ref.**	
1	0.864	[0.700, 1.067]
2–3	0.950	[0.801, 1.126]
Parents education		
Parents with secondary or higher	**Ref.**	
Parents without education	0.423***	[0.271, 0.660]
Parents with primary education	1.328	[0.923, 1.910]
Mother more educated than father	0.787	[0.553, 1.118]
Mother less educated than father	0.527***	[0.381, 0.730]
Maternal education		
Secondary or higher	**Ref.**	
No education	3.330***	[2.298, 4.825]
Primary	1.192	[0.899, 1.580]
Maternal age		
40 years or over	**Ref.**	
Under 25 years	1.024	[0.787, 1.332]
25–29 years	0.990	[0.779, 1.259]
30–34 years	1.013	[0.807, 1.270]
35–39 years	1.067	[0.851, 1.336]
Paternal education		
Secondary or higher	**Ref.**	
No education	1.176	[0.815, 1.695]
Primary	0.818ᵀ	[0.650, 1.029]
HOUSEHOLD FACTOR		
Age of Household		
40 years or over	**Ref.**	
< 25 years	2.217*	[1.195, 4.113]
25–29 years	1.424*	[1.050, 1.931]

Characteristic	OR	95% CI
30–34 years	1.212$^{\tau}$	[0.971, 1.513]
35–39 years	0.971	[0.797, 1.184]
Clean water		
Yes	**Ref.**	
No	1.580***	[1.248, 2.000]
Clean toilet		
Yes	**Ref.**	
No	1.694***	[1.340, 2.142]
Household size		
2–3	**Ref.**	
4–6	1.257*	[1.010, 1.565]
7 or over	1.454**	[1.142, 1.852]
Wealth index		
Rich	**Ref.**	
Poor	1.392**	[1.102, 1.758]
Middle	1.343**	[1.074, 1.681]
CONTEXTUAL FACTOR		
Place of residence		
Urban	**Ref.**	
Rural	2.308***	[1.834, 2.905]
Percentage of poor		
Low	**Ref.**	
High	4.843***	[3.806, 6.162]
% of educated women		
Very high	**Ref.**	
Low	0.760	[0.533, 1.085]
High	0.763	[0.563, 1.035]
Random effects		
Community var (constant)	0.577***	[0.422, 0.788]
Community > HH	2.341***	[1.868, 2.935]
ICC Community	0.093***	[0.070, 0.122]
ICC HH > Community	0.470***	[0.419, 0.522]
χ^2 de Wald	416.8***	

*Note: Authors' conception; *** Significant at 1 per thousand; ** Significant at the 1% level; *Significant at the 5% level; $^{\tau}$ Significant at the 10% level*

Decomposition results

Table 3 presents the decomposition estimates for changes in undernutrition among children U5 in Morocco between 2003 and 2018. Using the Fairlie decomposition method, the analysis identifies the factors contributing to the increase or decrease in the prevalence of undernutrition during this period. The selected variables account for 48.2% of the overall reduction in undernutrition prevalence. Specifically, a positive contribution reflects that a particular factor increased the prevalence of undernutrition between 2004 and 2018, while a negative contribution indicates that the factor contributed to a reduction in the prevalence of undernutrition.

The characteristics of the child and their immediate family offer valuable insights into the observed reductions in undernutrition. These factors are crucial in influencing the child's nutritional status, either alleviating or worsening the prevalence of undernutrition. A thorough understanding of these individual-level determinants is key to grasping how child undernutrition progresses and identifying effective interventions to further reduce its prevalence. Maternal education stands out as a significant factor, contributing 32.8% to the increase in the prevalence of undernutrition for mothers with no formal education (p = .001). This highlights that children of mothers without education are more likely to experience undernutrition.

In contrast, having a primary education contributed 9.6% to the reduction in undernutrition (p = .083), suggesting that even basic education reduces the risk of malnutrition by equipping mothers with essential knowledge regarding their children's health and nutrition. The child's age also plays a role in explaining changes in undernutrition. Children aged 24 to 35 months contributed 1.0% to the decrease in undernutrition prevalence (p = .001), indicating that this age group benefited from improved nutrition and care due to better dietary practices during weaning and early childhood. Child gender, particularly male, contributed 0.4% to the increase in undernutrition (p = .058). This suggests that boys may be slightly more vulnerable to undernutrition than girls, potentially due to gender-based differences in nutritional or healthcare practices.

In summary, individual-level factors play a crucial role in reducing undernutrition. Maternal education is a key determinant, with even basic education helping lower the risk of malnutrition. Younger children benefit from better care and nutrition, while boys seem slightly more vulnerable due to gender-based differences in healthcare and nutrition practices.

Additionally, household conditions, shaping the immediate environment in which children grow, significantly impact undernutrition outcomes. Factors such as access to clean water and sanitation are crucial in determining children's health and nutrition. The lack of access to clean water contributed 14.0% to the increase in undernutrition (p = .001), highlighting the health risks children face in households without clean drinking water. Waterborne diseases, like diarrhea, hinder nutrient absorption, affecting children's growth and overall health. Similarly, the absence of clean toilet facilities contributed 10.0% to the increase in undernutrition (p = .004). Poor sanitation exposes children to harmful pathogens and gastrointestinal diseases, directly impacting their ability to absorb nutrients and grow healthily. Economic conditions within households are crucial in reducing malnutrition. Poor households contributed 12.4% to the reduction in undernutrition (p < .001), showing how improved living standards among low-income families helped decrease child malnutrition. Poverty alleviation programs, economic growth, and social support initiatives have played a key role in improving household conditions and enabling better access to food and healthcare. Households headed by individuals under 25 years old contributed 1.4% to the increase in undernutrition (p = .016), suggesting that younger household heads may lack the financial stability, experience, or knowledge needed to ensure proper nutrition and healthcare for their children.

In brief, household-level factors significantly impact undernutrition, including access to clean water, sanitation, and economic stability. Lack of essential services increases the risk, while improved living standards help reduce it. Younger household heads may struggle due to limited resources. Overall, these conditions shape children's health and nutrition, influencing both positive and negative trends in undernutrition.

Finally, contextual factors such as socioeconomic and geographic conditions significantly influence child nutrition outcomes and contribute to regional disparities in undernutrition. Similar patterns of inequality in urban child undernutrition have been observed in India, where decomposition analysis revealed significant socioeconomic disparities within urban populations (Srivastava et al., 2020). Living in rural areas increases the risk of undernutrition, as children face limited access to essential services like healthcare, clean water, and education. Additionally, regions with a high percentage of educated women show improved child nutrition outcomes, with maternal education contributing positively to better healthcare decisions and dietary practices. Addressing rural infrastructure gaps and enhancing maternal education are key strategies for reducing undernutrition.

Table 3: Decomposition Estimates for Undernutrition Among Children Aged Under Five in Morocco, 2003–2004 to 2018

Characteristic	Coefficient	% Contribution
INDIVIDUAL FACTOR		
Child age months		
48–59 months	***Ref.***	
Under 6 months	- 0.00002	- 0.02
6–11 months	- 0.000001	-0.001
12–23 months	- 0.00031	-0.3
24–35 months	- 0.00089***	-1.0
36–47 months	0.000239	0.3
Sex of child		
Female	***Ref.***	
Male	0.000358*	0.4
Child rank		***-1.3***
4 or over	***Ref.***	
1	-0.00079	-0.9
2–3	-0.00044	-0.5
Parents education		
Parents with secondary or higher	***Ref.***	
Parents without education	-0.01957	-21.1
Parents with primary education	-0.00004	-0.04
Mother more educated than father	0.001505	1.6
Mother less educated than father	-0.00079	-0.9
Maternal education		
Secondary or higher	***Ref.***	
No education	.030467***	32.8
Primary	-0.008953*	-9.6
Maternal age		
40 years or over	***Ref.***	
Under 25 years	-0.000453	-0.5
25–29 years	0.000159	0.2
30–34 years	0.000021	0.02
35–39 years	-0.000048	-0.1
Paternal education		
Secondary or higher	***Ref.***	
No education	0.005838	6.3

Characteristic	Coefficient	% Contribution
Primary	0.005746	6.2
HOUSEHOLD FACTOR		
Age of Household		**2.3**
40 years or over	***Ref.***	
< 25 years	0.001270**	1.4
25–29 years	0.000662	0.7
30–34 years	0.000007	0.01
35–39 years	0.000176	0.2
Clean water		
Yes	***Ref.***	
No	0.012944***	14.0
Clean toilet		
Yes	***Ref.***	
No	0.009251***	10.0
Household size		
2–3	***Ref.***	
4–6	0.000290	0.3
7 or over	0.001036	1.1
Wealth index		
Rich	***Ref.***	
Poor	-0.011478	-12.4
Middle	0.001784*	1.9
CONTEXTUAL FACTOR		
Place of residence		
Urban	***Ref.***	
Rural	0.001249**	1.3
Percentage of poor		
Low	***Ref.***	
High	0.007435*	8.0
% of educated women		
Very high	***Ref.***	
Low	0.000416τ	0.4
High	0.007679τ	8.3
Total contribution		**48.2**
N (2003–2004)		5,484
N (2018)		6,064
Predictive probability of being undernourished in 2003–2004 (p1)		0.2890
Predictive probability of being undernourished in 2018 (p2)		0.1962
Difference (p1–p2)		0.0928
Total explained		0.0447

*Note: Authors' conception; *** Significant at 1 per thousand; ** Significant at the 1% level; * Significant at the 5% level; τ Significant at the 10% level*

Discussions

Since undernutrition results from the cumulative impact of fluctuating socioeconomic, health,

and nutritional challenges over time, continuous evaluation of the underlying factors is essential to accelerate its reduction. According to Smith and Haddad (2015), socioeconomic status, access to healthcare, and maternal education are key determinants influencing child nutrition outcomes, with disparities often persisting in different regions. Despite significant improvements in reducing undernutrition among children U5 in Morocco, with a rate of 18.4% in 2018, regional disparities persist, highlighting the need for further efforts to enhance children's nutritional outcomes nationwide.

Individual factors influencing child undernutrition

The characteristics of the child and their immediate family offer valuable insights into the observed reductions in undernutrition. They play a significant role in influencing the child's nutritional status, either mitigating or exacerbating the risk of malnutrition. Understanding these individual-level determinants is crucial for identifying effective interventions to further reduce child malnutrition. While individual factors are foundational, their impact is closely linked to household and contextual factors that provide the environment in which children grow and develop.

Maternal education stands out as a key individual factor, contributing to the increase in undernutrition among children of mothers without formal education. This underscores how lack of education hinders mothers' ability to apply adequate knowledge about nutrition, hygiene, and healthcare, directly affecting their children's nutritional well-being. Conversely, even basic education contributes significantly to the reduction of undernutrition by equipping mothers with the knowledge to better care for their children. This is corroborated by studies from West African countries and urban slums of Nairobi, which show that higher maternal education levels are strongly linked to improved child nutrition outcomes (Abuya et al., 2012; Nankinga et al., 2019). Such evidence emphasizes the importance of investing in maternal education at both basic and higher levels as a key strategy to combat malnutrition and enhance child health (Yorke et al., 2023).

The child's age plays a significant role in explaining the reduction in undernutrition. Children aged 24 to 35 months show notable improvements in nutritional status, benefiting from better dietary practices during crucial weaning and early childhood. Global research highlights the importance of the first 1,000 days of life (from conception to two years) as the most critical period for preventing undernutrition. Improvements in healthcare, nutrition, and growth monitoring during this window significantly reduce the risk of malnutrition (Dewey & Begum, 2011). Additionally, research shows that undernutrition typically peaks around 23 months, with the likelihood of new cases decreasing after this age, underscoring the importance of early interventions (Keats, 2021; Shrimpton et al., 2001).

Child gender also influences undernutrition, with boys slightly more vulnerable than girls. This is reflected in their higher likelihood of undernutrition, a trend observed in assorted studies. Biological factors, such as boys having higher energy needs and faster growth rates, may contribute to this vulnerability, especially in resource-constrained settings (Thurstans et al., 2020). Social and cultural feeding practices may also play a role, as evidenced in studies from Ethiopia, where boys were more likely to be undernourished than girls due to gender-specific caregiving patterns (Wang et al., 2021). These findings support the need for gender-sensitive nutritional interventions to address the unique risks boys face. These observations highlight the need for a gender-sensitive approach to addressing child malnutrition, ensuring that both boys and girls receive appropriate care and attention.

Household factors

Household conditions, which shape the immediate environment in which children grow and develop, significantly influence undernutrition outcomes. Lack of access to clean water, for example, is a major household-level factor, as it increases exposure to waterborne diseases like diarrhea, which hinder nutrient absorption and affect children's health. This study found that access to clean water is a critical determinant, supported by research from Saheed et al. (2022), which shows that inadequate water and sanitation facilities significantly increase undernutrition rates in young children. Addressing clean water access remains a priority for public health interventions to reduce undernutrition. Similarly, inadequate sanitation contributes to undernutrition by exposing children to harmful pathogens, leading to gastrointestinal diseases that impair nutrient absorption. Global reports also emphasize the crucial role of improving household access to safe drinking water, sanitation, and hygiene in tackling undernutrition, aligning with Sustainable Development Goal 6, which seeks to ensure clean water and sanitation for all (WHO, 2021). This highlights the intersection of household-level and broader public health policies in mitigating undernutrition risks.

Poor hygiene and sanitation conditions are linked to chronic undernutrition, particularly in vulnerable populations. Studies also show that improving sanitation facilities significantly reduces the risk of malnutrition. Therefore, improving infrastructure in these areas is crucial for curbing malnutrition-related diseases.

Economic conditions within households, particularly improving living standards among low-income families, play a vital role in reducing malnutrition. Programs like poverty alleviation initiatives, social support mechanisms, and economic growth have positively impacted household conditions, providing better access to food, healthcare, and sanitation. The World Bank (2022) highlighted the importance of these programs in addressing food insecurity and enhancing healthcare access. Economic stability allows families to afford preventive healthcare and treatment for common childhood diseases like diarrhea, reducing malnutrition (UNICEF et al., 2023). Improved financial conditions also support higher educational levels for mothers, fostering better child nutrition through informed feeding and care practices (Alao et al., 2021).

Households headed by individuals under 25 years old contributed to an increase in undernutrition, indicating that young household heads may lack the financial stability, knowledge, or experience necessary to provide adequate nutrition and healthcare for their children. Economic hardships, limited access to healthcare, and weak support systems exacerbate these challenges. UNICEF (2021) underscored that young parents in low-income settings are more likely to struggle with malnutrition due to insufficient resources and knowledge. The WHO's (2023) Joint Child Malnutrition Estimates further confirmed that children in households with younger parents face higher malnutrition risks due to food insecurity and healthcare challenges. These findings highlight the need for targeted support systems for young parents, particularly in low-resource settings.

Contextual factors

Contextual factors such as socioeconomic and geographic conditions also significantly influence child nutrition outcomes, contributing to regional disparities in undernutrition. Children in rural areas face greater risks due to limited access to healthcare, clean water, and

education. Srinivasan et al. (2013) and Fotso (2007) highlighted similar challenges for children in rural areas of Bangladesh, Nepal, and sub-Saharan Africa, where infrastructural gaps perpetuate malnutrition. In Morocco, significant regional disparities remain between urban and rural areas, with rural regions often lagging in healthcare infrastructure and access to clean water. Addressing these disparities by improving rural infrastructure is essential for reducing malnutrition rates in these regions. Rural development programs focusing on clean water, healthcare, and education could substantially reduce these gaps.

Moreover, regions with higher percentages of educated women show improved child nutrition outcomes, reinforcing the transformative role of maternal education in reducing undernutrition. Educated mothers are better equipped to make informed healthcare decisions and improve their children's dietary practices (Fotso, 2007; Smith & Haddad, 2000). As a result, increasing maternal education remains a key strategy for addressing child malnutrition in regions with low education levels. This underscores the need for sustained investments in maternal education as a cornerstone for regional development and improved child health.

Individual, household, and contextual factors are critical in shaping undernutrition outcomes. Interventions that focus on enhancing maternal education, improving household conditions, and addressing socioeconomic disparities, particularly in rural areas, are essential to sustaining the reduction in child malnutrition. These findings highlight the importance of a multifaceted approach in combating undernutrition, ensuring that both immediate and underlying causes are addressed to improve the overall nutritional well-being of children.

Conclusion and recommendations

This article aimed to explore the key determinants influencing the reduction of childhood undernutrition in Morocco between 2003 and 2018. Decomposition analysis examined how individual, household, and contextual factors contributed to this positive trend.

The findings highlight key areas where progress has been made and challenges persist, providing actionable insights for future policy interventions.

The study identifies maternal education as crucial in improving child nutrition outcomes. Children of mothers with no formal education are significantly more vulnerable to undernutrition. On the other hand, even a basic level of maternal education acts as a protective measure, equipping mothers with the knowledge and resources needed to care for their children effectively. This emphasizes that investing in maternal education is an equity issue and a fundamental driver of improved child nutrition. Targeting rural and marginalized areas where limited access to education is vital.

Access to clean water and sanitation is pivotal in reducing malnutrition at the household level. Poor access to these essential services leads to diarrhea, which hinders nutrient absorption and exacerbates malnutrition. The study shows that targeted infrastructure improvements, especially in underserved rural areas, are vital to mitigating these risks. Additionally, economic conditions significantly influence child nutrition. Poverty alleviation programs have positively impacted child health by enhancing access to food, healthcare, and better living conditions. Nonetheless, households headed by individuals under the age of twenty-five face heightened economic challenges, signaling a need for specific support programs tailored to the needs of young families.

The study underscores significant regional disparities. Rural children face greater risks of undernutrition due to limited access to healthcare, education, clean water, and sanitation. This finding reinforces the need for geographically targeted interventions prioritizing healthcare infrastructure, women's educational opportunities, and rural sanitation and water supply systems investments. Addressing these regional disparities is critical to achieving equitable progress in child nutrition.

The analysis highlights the intricate relationship between socioeconomic and geographic factors, necessitating a comprehensive approach to improving child nutrition. Programs should integrate efforts across sectors—such as education, healthcare, and infrastructure—while tailoring solutions to the specific socioeconomic contexts of affected populations. Given Morocco's commitment to the 2030 Sustainable Development Goals, particularly SDG 2, addressing undernutrition is a key priority. This study demonstrates that maternal education and household-level conditions are central levers for reducing undernutrition. Policies should, therefore, focus on expanding access to education for women and girls, improving rural sanitation and water supply, and supporting vulnerable households through tailored poverty alleviation programs.

In conclusion, while Morocco has made substantial progress in reducing childhood undernutrition, significant challenges remain in addressing the socioeconomic and geographic disparities perpetuating malnutrition in rural areas. This study provides evidence-based recommendations for focusing interventions on maternal education, rural infrastructure, and tailored poverty alleviation programs. By addressing these specific determinants, policymakers can make further progress in combating undernutrition and ensure that every child has the opportunity to thrive.

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