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Temporal socio-economic inequalities in the double burden of malnutrition (DBM) among under-five Children: An analysis of within- and between-group disparities in 20 sub-Saharan African countries (2004–2024)

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ABSTRACT

Background: The double burden of malnutrition (DBM) in sub-Saharan Africa is a pressing public health issue, particularly among children under five years old. DBM encompasses both undernutrition (stunting) and overnutrition (overweight) within the same population, often shaped by socio-economic disparities. Addressing DBM in early childhood is vital, as malnutrition can lead to long-term health, cognitive, and developmental challenges.

Methods: Using nationally representative data from the Demographic and Health Surveys (DHS) across 20 sub-Saharan African countries, this study examines temporal socio-economic inequalities in DBM. Countries include Zimbabwe, Kenya, Nigeria, and Mozambique, among others. DBM was defined using anthropometric measures, while socio-economic status (SES) was categorized as poor, middle, or rich. Temporal trends were analyzed, and inequalities were quantified using Erreygers Normalized

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Overweight
Under-five children
Theil index
Erreygers normalized concentration index

Concentration Indices (ENCI) and Theil indices to explore within- and between-group disparities by SES and urban/rural residence.
Results: DBM prevalence across countries ranged from 0.2 % to 4.6 %. Declines were noted in Zimbabwe and Kenya. Socio-economic inequalities were significant, with overnutrition increasingly concentrated in wealthier households, while undernutrition remained prevalent among poorer populations. Theil index analyses revealed within-group disparities as the primary drivers of overall inequality, particularly in urban wealthier populations, though rural and low-SES groups also contributed significantly in countries like Senegal and Mali.
Conclusion: DBM is still present in sub-Saharan Africa and is driven by socio-economic inequalities. Targeted interventions focusing on improving access to nutritious food, healthcare, and education for vulnerable populations, particularly in rural and low-SES groups, are essential to reduce malnutrition disparities.

1. Introduction

Malnutrition remains a critical public health issue, particularly in low- and middle-income countries (LMICs), where it disproportionately affects vulnerable populations, especially children under the age of five [1–3]. Malnutrition can manifest in several forms, including undernutrition, which presents as stunting (chronic malnutrition), wasting (acute malnutrition), and micronutrient deficiencies, as well as overnutrition, characterized by overweight, obesity, and diet-related noncommunicable diseases [4]. The coexistence of these two extremes; undernutrition and overnutrition within the same population or even within the same household is termed the double burden of malnutrition (DBM) [5]. Addressing DBM is critical for improving health outcomes in sub-Saharan Africa, particularly among children under five, who are at a crucial stage of development [6]. DBM in this population is especially concerning as it leads to adverse health, growth, and cognitive development outcomes, which can have lasting effects into adulthood [7–9].

In Africa, the DBM is public health challenge, as children under five years of age are disproportionately affected by both forms of malnutrition [10]. The evolving nature of DBM in Africa reflects broader global trends driven by rapid urbanization, changing dietary patterns, and socio-economic transitions. These transitions are contributing to shifts in dietary behaviours, with a move towards energy-dense, nutrient-poor foods, particularly in urban settings [11–14]. However, despite growing awareness, socio-economic inequalities in access to healthcare, nutrition, and education further exacerbate the problem. Vulnerable groups, including children from poorer households, are particularly at risk of suffering from the long-term consequences of malnutrition [1]. In sub-Saharan Africa, malnutrition is a complex and multifaceted issue. According to recent estimates, approximately 35 % of children under five are stunted, 10 % are wasted, and 5 % are overweight [15]. Stunting, the result of chronic undernutrition, has long-term consequences for physical and cognitive development, while wasting reflects acute malnutrition, leading to higher risks of morbidity and mortality [16]. Conversely, the rising rates of overweight and obesity in young children, particularly in urban areas, indicate a shift in dietary patterns often associated with increased consumption of processed foods and a more sedentary lifestyle [17,18]. These dual challenges make it increasingly difficult to address malnutrition holistically in young children.

Studies examining the prevalence of DBM in Africa have shown significant variation across countries and regions [4,19–29]. Socio-economic inequalities, particularly income inequalities, are key drivers of DBM [30,31]. Families with lower incomes are more likely to experience food insecurity, which limits access to diverse and nutritious diets, leading to higher rates of stunting and wasting among children. At the same time, as household incomes rise, families may shift towards more affordable, energy-dense, but nutrient-poor foods, contributing to overweight and obesity among children. This paradox highlights the complex relationship between socio-economic status and malnutrition in sub-Saharan Africa.

The rapid urbanization seen across much of Africa has also contributed to changing dietary patterns, which are closely linked to the rise in overnutrition [11]. Urban populations often have greater access to food markets and a more diverse array of food options. However, they are also more exposed to unhealthy food environments characterized by the proliferation of fast foods and processed snacks, which are high in fats, sugars, and refined carbohydrates [32–34]. These shifts are contributing to the rise in childhood obesity, particularly in urban areas where children from wealthier households are more likely to have access to these foods. However, even poorer households in urban areas are not immune to this trend, as they may lack access to nutritious foods due to the rising costs of healthy options [35]. This dietary transition is occurring alongside persistent undernutrition in many rural areas, creating a complex landscape of malnutrition in sub-Saharan Africa.

Recent evidence suggests that socio-economic inequalities in malnutrition are persistent and, in some cases, widening in sub-Saharan Africa. For instance, studies conducted in Zambia and Uganda reveal that children from poorer households are more likely to experience undernutrition compared to their wealthier counterparts [36,37]. In Zambia, children from lower socio-economic groups were significantly more likely to be stunted or underweight, while children from higher-income households faced an increasing risk of becoming overweight due to shifts in dietary patterns [37]. Similar trends have been observed in Uganda, where data shows that despite some progress in reducing overall malnutrition rates, disparities between socio-economic groups remain significant [36]. These findings highlight the need for targeted public health interventions to address the root causes of socio-economic inequalities in child malnutrition.

The rise in overnutrition among children under five is a relatively recent phenomenon but one that requires urgent attention. Studies have shown that overweight and obesity are becoming more prevalent in both urban and rural areas, with urbanization and changing dietary patterns playing a major role [38–42]. In South Africa, the prevalence of childhood obesity has increased dramatically, particularly in urban areas where access to high-calorie, nutrient-poor foods is greater [43]. Socio-economic disparities in DBM are not unique to Africa but are part of a global trend. Countries in Latin America and Asia have also experienced

the rise of the double burden of malnutrition, particularly in nations undergoing rapid economic transitions. In Brazil and Mexico, the prevalence of undernutrition has declined significantly over the past few decades, but this progress has been accompanied by a concurrent rise in overnutrition, particularly among urban and wealthier populations [44].

To effectively scale up interventions addressing the DBM among children, it is essential to tackle disparities across socioeconomic and residential groups. However, most studies in Sub-Saharan Africa (SSA) have predominantly focused on single time periods, limiting the ability to analyze temporal trends comprehensively [10,45–48]. Moreover, these studies often emphasize between-group inequalities, such as differences across socioeconomic and residential groups, while neglecting within-group disparities. This approach risks overlooking vulnerabilities among the most disadvantaged subpopulations, potentially masking critical areas for intervention.

To this end, this study set out to investigate the temporal socioeconomic inequalities in the individual-level double burden of malnutrition among children under five in ten select sub-Saharan African countries. The specific objectives are to: (1) examine intra-country trends in individual-level DBM among children under-five; (2) analyze temporal inequalities in individual-level DBM between socioeconomic and residential groups; (3) examine temporal inequalities within these groups to identify hidden disparities; and (4) Evaluate the contribution of both between-group and within-group inequalities to overall disparities in individual-level DBM.

By uncovering trends and inequalities within and between socioeconomic and residential groups, the findings can guide targeted interventions to address the most vulnerable populations. Understanding the contributions of between-group and within-group disparities to overall inequalities enables policymakers to design more equitable strategies that prioritize high-risk subpopulations. Such evidence is essential for shaping nutrition policies, resource allocation, and scaling up effective interventions to combat DBM, ultimately contributing to the achievement of Sustainable Development Goals (SDGs) related to health, nutrition, and social equity in SSA.

2. Methods

2.1. Data

This study draws on publicly available, nationally representative data from the Demographic and Health Surveys (DHS) [49] conducted in selected Sub-Saharan African countries. The countries included in this analysis are Zimbabwe (2005/06 & 2015), Zambia (2007 & 2018), Sierra Leone (2008 & 2019), Senegal (2012/13 & 2023), Mali (2006 & 2018), Malawi (2004 & 2015), Kenya (2008/09 & 2022), Guinea (2005 & 2018), Ethiopia (2005 & 2019), Burundi (2010 & 2016), Mozambique (2011 & 2022/23), Lesotho (2014 & 2023/24), Nigeria (2008 & 2018), Ghana (2008 & 2022), Uganda (2006 & 2016), Tanzania (2010 & 2022), Rwanda (2010 & 2019/20), Burkina Faso (2010 & 2021), Cameroon (2004 & 2018), and Cote d'Ivoire (2011/12 & 2021). This study builds on a previous analysis by Alaba et al. (2023) [6], which examined the double burden of malnutrition in some of these nations. More countries were added to the study owing to the ongoing nutritional transition inn Africa [14] and the availability of recent DHS data for secondary analysis. To facilitate a more comprehensive temporal analysis, survey data collected at least 10 years apart were used, with the exception of Burundi, where such data were unavailable. The analysis focuses on children under the age of five years (i.e., below 60 months), with data sourced from the DHS women's questionnaire [49]. The surveys offer comprehensive and comparable data on various indicators of health and nutrition [49], providing a foundation for the investigation of within- and between-group disparities in DBM across socio-economic strata in these countries.

2.2. Study variables

2.2.1. Stunting, wasting, underweight and overweight

The key anthropometric indicators stunting, wasting, underweight, and overweight were defined according to the World Health Organization (WHO) growth standards [50]. Each variable was operationalized as follows.

- **Stunting** was coded as a binary variable, with children who were not stunted (height-for-age Z-score ≥ -2 SD relative to the median of the WHO Child Growth Standards) assigned a value of "0″, and those stunted (Z-score < -2 SD) assigned a value of "1" [51].
- **Wasting** was also treated as a binary variable, where children who were not wasted (weight-for-height Z-score ≥ -2 SD relative to the median of the WHO Child Growth Standards) were coded as "0″, and those who were wasted (Z-score < -2 SD) as "1" [51].
- **Underweight** was similarly represented as a binary variable, with children who were not underweight (weight-for-age Z-score ≥ -2 SD relative to the median of the WHO Child Growth Standards) coded as "0″, and those underweight (Z-score < -2 SD relative to the median of the WHO Child Growth Standards) as "1" [51].
- **Overweight** was defined as a weight-for-height Z-score more than 2 standard deviations above the reference population median [51]. Children with a Z-score above $+2$ SD were coded as "1" (overweight), and those below $+2$ SD as "0" (not overweight).

2.2.2. Individual-level double burden of malnutrition (DBM)

The primary outcome variable, individual-level DBM, was derived by combining the indicators of undernutrition (stunting) and overnutrition (overweight). DBM was defined as the coexistence of both undernutrition and overnutrition in the same individual. Specifically, a child with DBM had a "1″ in the stunting indicator and a "1″ in the overweight indicator. Children without both forms of malnutrition were assigned a value of "0".

2.2.3. Socio-economic status (SES) and place of residence

Socio-economic status (SES) was assessed using the wealth index computed by the DHS [52]. The wealth index, originally categorized into five quintiles (poorest (Q1), poorer (Q2), middle (Q3), richer (Q4), and richest (Q5)), was recoded into three categories: 0 = poor (Q1 and Q2), 1 = middle (Q3), and 2 = rich (Q4 and Q5). Place of residence, another key variable, was classified as a binary variable: urban areas were coded as "1″ and rural areas as "0".

2.3. Statistical analysis

Data analysis was carried out using STATA 17. Univariate and bivariate analyses were first carried out to describe the sample and explore patterns of DBM. Afterwards, Erreygers Normalized Concentration indices (ENCI) and Theil indices were computed to understand DBM related inequalities.

2.4. Erreygers Normalized Concentration indices (ENCI)

To quantify inequality of DBM across different socio-economic

groups, the ENCI was employed [53–55]. The ECNI is particularly suited for bounded variables, such as the dichotomous measure of DBM used in this study (DBM present = 1, DBM absent = 0), as it accounts for the limited range of the variable and ensures comparability across contexts. The values of this index ranges from −1 to +1. A positive ENCI would indicate that the DBM is more concentrated among children from the wealthier socio-economic groups and vice versa. An ENCI of zero denotes perfect inequality, and in this case, would mean that DBM is equally distributed across socio-economic groups.

The Erreygers normalized concentration index is calculated as shown below;

$$E(C) = \frac{4\mu}{b-a}C$$

Where:

μ is the mean of the health variable; DBM among under-fives

b and a are the upper and lower bounds of the health variable, respectively.

C is the traditional concentration index.

The traditional concentration index is calculated as shown below;

$$C = \frac{2}{\mu}\,\mathrm{Cov}\,(y, R)$$

Where:

y is the health variable (DBM).

μ is the mean of y.

R is the fractional rank of individuals in the distribution of SES.

Cov denotes the covariance between y and R.

For this study, the bounds of the DBM variable were b=1 and a=0, simplifying the ECNI formula to;

$$E(C) = 8.\ \mathrm{Cov}\ (y, R)$$

This approach ensures consistency and appropriateness when dealing with a binary health variable like DBM. The ECNI reflects inequality relative to socio-economic rank and provides a robust measure for understanding disparities. Recent guidelines [56], were reviewed to ensure that the application of ECNI in this study adheres to best practices for dichotomous health outcomes.

2.5. Theil indices

While the Erreygers Normalized Concentration Index (ENCI) provides a single summary measure of inequality, it does not offer insights into how inequality is distributed across different groups [53–55]. Therefore, this study sought to investigate the extent to which inequality in the double burden of malnutrition (DBM) is attributable to within-group disparities (e.g., within socio-economic status or place of residence) versus between-group disparities (e.g., between different socio-economic statuses or places of residence).

To achieve this, the study employed Theil indices, a Generalized Entropy (GE) measure, which allows for the decomposition of total inequality into its within-group and between-group components [57]. The Theil index is particularly useful in distinguishing how much of the overall inequality stems from variations within smaller groups (such as within regions or socio-economic groups) and how much arises from differences between these groups [57]. The index ranges from zero, indicating perfect equality, to infinity, with higher values indicating greater inequality. In this study, the overall Theil indices were calculated and further stratified by place of residence and socio-economic status (SES). Subsequently, the total inequality was decomposed to quantify the contributions of within-group and between-group components to the overall inequality.

3. Results

3.1. Descriptive statistics

According to Table 1, while many countries achieved significant improvements, others faced persistent or emerging challenges in addressing child malnutrition. Kenya made substantial progress between 2008/9 and 2022. Stunting decreased from 35.33 % to 17.62 %, wasting from 6.72 % to 4.86 %, and underweight prevalence from 14.89 % to 9.82 %. Overweight prevalence declined from 4.66 % to 3.22 %, while the prevalence of DBM dropped sharply from 2.25 % to 0.51 %. Malawi also saw significant reductions between 2004 and 2015/16. Stunting decreased from 47.93 % to 37.22 %, wasting from 5.15 % to 2.73 %, and underweight prevalence from 17.86 % to 11.22 %. Overweight prevalence declined modestly from 5.90 % to 4.56 %, with DBM reducing from 2.51 % to 1.90 %. Burkina Faso also recorded notable progress between 2010 and 2021. Stunting fell from 34.67 % to 22.63 %, wasting from 15.48 % to 10.63 %, and underweight prevalence dropped by 7 percentage points. Overweight prevalence remained low, decreasing from 2.37 % to 1.61 %, while DBM dropped from 1.34 % to 0.74 %. Zimbabwe also showed improvements between 2005/6 and 2015. Stunting dropped from 34.64 % to 26.88 %, wasting from 6.92 % to 3.18 %, and underweight prevalence from 11.21 % to 7.92 %. Overweight prevalence fell from 7.99 % to 5.60 %, with DBM declining from 3.76 % to 1.76 %.

In contrast, Burundi experienced limited progress between 2010 and 2016. Underweight prevalence worsened, increasing from 27.41 % to 29.19 %, while stunting remained high, with a slight decline from 57.83 % to 56.17 %. Wasting showed minimal improvement, falling marginally from 5.84 % to 5.10 %. Although overweight prevalence decreased from 2.68 % to 1.36 %, the persistent high stunting and worsening underweight underscore systemic challenges like political instability and inadequate healthcare. Senegal exhibited mixed outcomes between 2012 and 2023. While stunting decreased slightly from 18.75 % to 17.49 % and overweight prevalence fell from 1.41 % to 1.13 %, wasting rose from 8.86 % to 10.19 %, and underweight prevalence increased from 14.55 % to 15.25 %, signalling stagnation and/or emerging challenges in managing acute malnutrition. Cameroon also painted a mixed picture between 2004 and 2018. Stunting decreased from 31.78 % to 28.97 %, and underweight prevalence dropped from 15.92 % to 10.84 %. However, overweight prevalence more than doubled, rising from 5.19 % to 11.00 %, contributing to an increase in DBM from 1.58 % to 4.25 %, highlighting the growing issue of overnutrition alongside undernutrition.

Table 2 highlights the changes in the distribution of children with DBM among different groups. In Zimbabwe, the distribution of DBM cases shifted across socioeconomic and geographic groups between 2005/06 and 2015. The share of DBM cases among children in the poorest wealth quintile increased from 18.36 % to 24.04 %, while the share among the richest quintile declined from 19.44 % to 8.08 %. This suggests that DBM has become more concentrated among poorer households, though this does not necessarily reflect an increase in DBM prevalence within the poorest group. Urban areas accounted for a growing proportion of DBM cases (from 27.54 % to 31.45 %), while rural areas' share declined (from 72.46 % to 68.55 %), indicating a shifting distribution of DBM toward urban populations (see Table 3).

In Mali, between 2006 and 2018, the share of DBM cases in the poorest quintile declined from 18.93 % to 11.74 %, while the richest quintile's share rose from 13.88 % to 22.30 %, reflecting a shift in the

Table 1
The proportion of under-five children with DBM for 20 countries in SSA, various years.

Country	Year	Stunting (%) [Confidence Interval]	Wasting (%) [Confidence Interval]	Underweight (%) [Confidence Interval]	Overweight (%) [Confidence Interval]	DBM (%) [Confidence Interval]
Zimbabwe	2005/6	34.64 [32.64, 36.64]	6.92 [6.05, 7.80]	11.21 [10.15, 12.26]	7.99 [7.04, 8.94]	3.76 [3.16, 4.36]
	2015	26.88 [25.30, 28.47]	3.18 [2.66, 3.70]	7.92 [7.07, 8.76]	5.60 [4.89, 6.30]	1.76 [1.37, 2.16]
Zambia	2007	45.51 [43.46, 47.56]	5.20 [4.52, 5.88]	13.13 [12.03, 14.23]	7.89 [6.93, 8.85]	4.61 [3.92, 5.30]
	2018	34.61 [33.32, 35.91]	4.23 [3.63, 4.84]	11.35 [10.46, 12.23]	5.23 [4.61, 5.86]	2.34 [1.89, 2.80]
Siera Leonne	2008	36.48 [33.99, 38.97]	10.19 [8.88, 11.51]	17.34 [15.32, 19.35]	8.43 [6.99, 9.86]	3.91 [3.15, 4.68]
	2019	29.59 [27.87, 31.30]	5.39 [4.62, 6.15]	12.27 [11.11, 13.44]	4.54 [3.70, 5.39]	1.79 [1.35, 2.23]
Senegal	2012/13	18.75 [17.13, 20.36]	8.86 [7.76, 9.96]	14.55 [13.05, 16.05]	1.41 [1.01, 1.80]	0.26 [0.10, 0.43]
	2023	17.49 [15.88, 19.09]	10.19 [8.88, 11.49]	15.25 [13.88, 16.62]	1.13 [0.33, 1.93]	0.20 [0.00, 0.40]
Mali	2006	37.78 [36.09, 39.46]	15.23 [14.29, 16.17]	23.82 [22.55, 25.09]	3.96 [3.33, 4.60]	1.82 [1.50, 2.13]
	2018	26.95 [25.52, 28.38]	9.00 [8.21, 9.79]	17.72 [16.59, 18.84]	1.97 [1.63, 2.31]	0.80 [0.60, 0.99]
Malawi	2004	47.93 [46.35, 49.52]	5.15 [4.47, 5.82]	17.86 [16.84, 18.88]	5.90 [5.30, 6.50]	2.51 [2.17, 2.85]
	2015/16	37.22 [35.57, 38.88]	2.73 [2.20, 3.25]	11.22 [10.21, 12.24]	4.56 [3.86, 5.25]	1.90 [1.42, 2.38]
Kenya	2008/9	35.33 [33.19, 37.46]	6.72 [5.71, 7.74]	14.89 [13.01, 16.76]	4.66 [3.96, 5.37]	2.25 [1.78, 2.72]
	2022	17.62 [16.73, 18.51]	4.86 [4.41, 5.32]	9.82 [9.15, 10.48]	3.22 [2.83, 3.61]	0.51 [0.38, 0.64]
Guinea	2005	34.93 [32.37, 37.49]	9.56 [8.22, 10.90]	22.64 [20.53, 24.76]	2.88 [2.16, 3.60]	0.88 [0.52, 1.23]
	2018	30.43 [28.63, 32.23]	9.22 [8.03, 10.41]	15.96 [14.65, 17.26]	5.62 [4.63, 6.60]	3.08 [2.39, 3.77]
Ethiopia	2005	46.61 [44.23, 48.98]	10.55 [9.27, 11.83]	33.46 [31.41, 35.51]	2.70 [1.97, 3.44]	0.97 [0.54, 1.40]
	2019	36.85 [34.14, 39.55]	7.02 [5.79, 8.25]	20.65 [17.94, 23.36]	2.26 [1.32, 3.20]	0.95 [0.35, 1.54]
Burundi	2010	57.83 [55.77, 59.88]	5.84 [4.85, 6.82]	27.41 [25.62, 29.20]	2.68 [2.00, 3.37]	1.79 [1.22, 2.37]
	2016/17	56.17 [54.31, 58.04]	5.10 [4.45, 5.74]	29.19 [27.65, 30.73]	1.36 [1.04, 1.69]	0.72 [0.48, 0.97]
Mozambique	2011	42.77 [41.04, 44.49]	5.91 [5.25, 6.58]	14.17 [13.11, 15.23]	7.38 [6.65, 8.11]	4.30 [3.66, 4.93]
	2022/23	36.89 [34.34, 39.44]	3.80 [3.03, 4.56]	13.56 [11.93, 15.20]	3.19 [2.55, 3.83]	1.29 [0.89, 1.70]
Lesotho	2014	33.34 [30.72, 35.96]	2.80 [1.99, 3.60]	9.78 [8.17, 11.40]	7.38 [6.05, 8.71]	2.48 [1.68, 3.29]
	2023/24	35.72 [32.58, 38.86]	1.71 [0.96, 2.46]	12.17 [9.80, 14.54]	6.88 [5.04, 8.73]	1.80 [0.96, 2.64]
Nigeria	2008	40.72 [39.43, 42.01]	13.91 [13.01, 14.82]	17.87 [16.96, 18.78]	8.77 [8.22, 9.33]	4.25 [3.94, 4.57]
	2018	36.89 [35.34, 38.44]	6.81 [6.23, 7.38]	21.33 [20.14, 22.53]	2.06 [1.74, 2.38]	0.81 [0.59, 1.03]
Ghana	2008	27.95 [25.65, 30.26]	8.50 [7.40, 9.60]	12.08 [10.63, 13.52]	5.25 [4.09, 6.42]	2.18 [1.49, 2.87]
	2022	17.48 [15.85, 19.11]	5.96 [5.01, 6.90]	12.04 [10.69, 13.38]	1.96 [1.45, 2.47]	0.32 [0.13, 0.52]
Uganda	2006	38.11 [35.78, 40.44]	6.14 [5.11, 7.16]	14.72 [13.07, 16.37]	4.72 [3.70, 5.73]	1.77 [1.19, 2.36]
	2016	28.97 [27.30, 30.64]	3.55 [2.96, 4.14]	10.00 [8.98, 11.01]	3.74 [3.13, 4.34]	1.08 [0.76, 1.39]
Tanzania	2010	42.17 [40.35, 43.98]	4.75 [4.14, 5.37]	14.90 [13.60, 16.19]	5.05 [4.38, 5.72]	2.52 [2.10, 2.95]
	2022	30.16 [28.07, 32.24]	3.32 [2.74, 3.89]	11.66 [10.50, 12.81]	3.49 [2.91, 4.08]	1.03 [0.74, 1.32]
Rwanda	2010	44.35 [42.43, 46.28]	2.81 [2.28, 3.35]	11.23 [10.18, 12.27]	6.73 [5.94, 7.52]	3.43 [2.86, 4.01]
	2019/20	33.27 [31.36, 35.17]	1.12 [0.75, 1.49]	7.65 [6.73, 8.58]	5.62 [4.81, 6.43]	1.80 [1.36, 2.24]
Burkina Faso	2010	34.67 [33.08, 36.26]	15.48 [14.15, 16.80]	24.36 [22.99, 25.72]	2.37 [1.89, 2.84]	1.34 [1.01, 1.66]
	2021	22.63 [21.07, 24.19]	10.63 [9.47, 11.79]	17.33 [15.88, 18.78]	1.61 [1.20, 2.02]	0.74 [0.49, 0.99]
Cameroon	2004	31.78 [29.56, 34.00]	5.05 [4.19, 5.92]	15.92 [14.15, 17.69]	5.19 [4.21, 6.17]	1.58 [1.07, 2.09]
	2018	28.97 [26.85, 31.08]	4.31 [3.27, 5.35]	10.84 [8.90, 12.77]	11.00 [8.99, 13.01]	4.25 [3.06, 5.45]
Cote d'Ivoire	2011/12	23.93 [21.82, 26.04]	6.95 [5.76, 8.14]	16.84 [15.03, 18.64]	2.09 [1.52, 2.66]	0.52 [0.27, 0.77]
	2021	23.49 [21.77, 25.22]	8.37 [7.18, 9.56]	13.36 [11.97, 14.76]	3.26 [2.04, 4.47]	1.02 [0.63, 1.41]

concentration of DBM toward wealthier children. Urban areas also accounted for a larger proportion of DBM cases over time (from 22.47 % to 26.83 %), while the rural share declined modestly (from 77.43 % to 73.17 %). In Lesotho, the richest quintile's share of DBM cases increased substantially, from 6.40 % in 2014 to 30.13 % in 2023/24, suggesting a redistribution of DBM toward higher-income children. Similarly, the share of DBM in urban areas rose sharply, from 12.60 % to 40.77 %, likely reflecting urbanization and changes in diet and lifestyle.

In Sierra Leone, there was a moderate increase in the share of DBM cases among the poorest quintile (from 21.05 % to 26.67 %) and the richest quintile (from 14.87 % to 21.39 %). Urban areas saw a growing share of DBM cases (from 30.41 % to 42.81 %), while rural areas' share declined, indicating a redistribution of the burden across geographic locations. In Ethiopia and Burundi, the DBM burden remains heavily rural. In Ethiopia, rural areas accounted for an increasing share of DBM cases (from 90.76 % in 2005 to 95.42 % in 2019), while the urban share declined. Similarly, in Burundi, the rural share remained dominant (93.94 % in 2016), despite a slight increase in urban share (from 4.28 % to 6.06 %). In both countries, the richest quintile's share of DBM cases declined from 17.61 % to 4.86 % in Ethiopia and from 18.60 % to 10.65 % in Burundi indicating a relative concentration of DBM among less wealthy groups.

In Malawi, the urban share of DBM cases dropped substantially, from 31.43 % in 2004 to 7.39 % in 2015/16, while the rural share increased from 86.57 % to 92.61 %, pointing to a growing concentration of DBM among rural children. In Cameroon, the distribution of DBM cases across both poor and rich quintiles increased, with the poorest quintile consistently representing a larger share. Urban areas saw a modest decline in their share of DBM cases (from 36.16 % to 29.82 %), while the rural share increased (from 63.84 % to 70.18 %), reflecting a shift in where DBM is concentrated. In Senegal, the richest quintile's share of DBM cases dropped to zero by 2023, down from 17.88 % in 2012, while urban areas' share increased, pointing to a redistribution of DBM away from wealthier households but still toward urban settings.

Table 2
The distribution of children with DBM across the different subgroups.

Country	Year	Estimation sample	Number of children with DBM	Socioeconomic Status		Residence Status	
				Q1 Poorest %	Q5 Richest %	Urban %	Rural %
Zimbabwe	2005/6	5785	206	18.36	19.44	27.54	72.46
	2015	6511	124	24.40	8.08	31.45	68.55
Zambia	2007	6237	285	31.90	8.12	19.57	80.43
	2018	10094	234	29.25	15.64	35.22	64.78
Siera Leonne	2008	3190	131	21.05	14.87	30.41	69.59
	2019	5556	100	26.67	21.39	42.81	57.19
Senegal	2012/13	7031	18	22.89	17.88	57.19	42.81
	2023	5373	9	25.25	0.00	62.83	37.17
Mali	2006	13144	277	18.93	13.88	22.47	77.43
	2018	9910	106	11.74	22.30	26.83	73.17
Malawi	2004	10667	294	24.79	13.42	31.43	86.57
	2015/16	6033	105	25.48	10.67	7.39	92.61
Kenya	2008/9	6092	149	30.39	12.54	14.52	85.48
	2022	20319	90	26.58	12.08	28.51	71.49
Guinea	2005	3130	30	23.23	12.96	21.33	78.67
	2018	4184	120	24.79	15.89	30.31	69.69
Ethiopia	2005	4855	50	26.81	17.61	9.24	90.76
	2019	5695	35	23.30	4.86	4.58	95.42
Burundi	2010	3794	68	13.48	18.60	4.28	95.72
	2016/17	6433	44	13.21	10.65	6.06	93.94
Mozambique	2011	10876	440	21.69	9.55	26.94	73.06
	2022/23	4646	53	18.45	6.06	13.28	86.72
Lesotho	2014	1981	54	30.40	6.40	12.60	87.40
	2023/24	1632	35	27.61	30.13	40.77	59.23
Nigeria	2008	26938	1213	23.52	15.88	27.16	72.84
	2018	12806	101	22.39	7.26	27.53	72.47
Ghana	2008	3056	63	19.71	11.46	43.04	56.96
	2022	5045	15	24.67	25.81	35.41	64.59
Uganda	2006	2866	49	23.02	14.23	5.87	94.13
	2016	5418	64	21.47	13.25	9.06	90.94
Tanzania	2010	8004	206	23.20	12.90	17.5	82.5
	2022	5744	68	26.01	7.08	16.53	83.47
Rwanda	2010	4417	147	26.57	10.97	5.86	94.14
	2019/20	4063	74	36.00	9.10	14.25	85.75
Burkina Faso	2010	7202	97	19.84	13.62	20.50	79.50
	2021	6565	48	22.95	7.78	13.60	86.40
Cameroon	2004	4189	60	15.67	5.99	36.16	63.84
	2018	5295	205	33.06	9.24	29.82	70.18
Cote d'Ivoire	2011/12	4238	23	7.45	17.48	62.03	37.97
	2021	5578	53	25.78	18.64	57.00	43.00

3.2. Concentration indices and curves

In Cameroon, DBM inequality worsened significantly between 2004 and 2018. Initially, the ENCI was nearly neutral at −0.001 ($p = 0.811$) [Table 3], indicating little inequality in DBM distribution. However, by 2018, the ENCI dropped to −0.020 ($p = 0.019$), reflecting a significant concentration of DBM among poorer populations. Similarly, in Rwanda, DBM has consistently been concentrated among poorer groups, with statistically significant ENCI values of −0.016 ($p = 0.009$) in 2010 and -0.012 ($p = 0.011$) in 2019/20. Although the gap narrowed slightly over time, DBM inequality remains a persistent issue in the country.

In Zambia, DBM inequality improved between 2007 and 2018. The ENCI in 2007 was −0.019 ($p = 0.004$) [Table 3], indicating a significant concentration of DBM among poorer groups. By 2018, the ENCI rose to −0.001 ($p = 0.729$), suggesting reduced inequality in DBM distribution, though the change was not statistically significant. Malawi experienced a slight reduction in DBM inequality over time. In 2004, the ENCI was −0.008 ($p = 0.039$), showing a significant concentration of DBM among poorer populations. By 2015/16, the ENCI rose to −0.007 ($p = 0.124$), reflecting a small, albeit statistically insignificant, improvement.

Some countries exhibited little to no change in the socioeconomic distribution of DBM. In Senegal, the ENCI remained neutral throughout the period, with values of 0.000 in 2012 and 2023 ($p = 0.989$ and $p = 0.912$, respectively) [Table 3], indicating no significant inequality in DBM distribution. Similar stability was observed in Burkina Faso, where the ENCI was 0.000 in 2010 and -0.002 in 2021 ($p = 0.856$ and $p = 0.454$, respectively), and in Ghana, where ENCI values stayed near zero during the observation period.

The dominance tests and Lorenz curves for the prevalence of the double burden of malnutrition (DBM) among children under five across 20 sub-Saharan African countries are presented in Supplementary: Figures 1–20 and Supplementary: Tables 1–20. These analyses account for Lorenz curve crossings with the line of equality, reflecting the role of socioeconomic status (SES) in driving DBM inequality.

In Zimbabwe (Supplementary: Figure 1; Supplementary: Table 1), SES showed limited explanatory power for DBM in 2005/06 (dominance: 0.001; fit: 0.002), which diminished completely by 2015 (both statistics: 0.000). Zambia (Supplementary: Figure 2; Supplementary: Table 2) exhibited moderate inequality in 2007 (dominance: 0.002; fit: 0.005), but no SES-driven disparities remained by 2018. Similarly, Sierra Leone (Supplementary: Figure 3; Supplementary: Table 3) and Senegal (Supplementary: Figure 4; Supplementary: Table 4) consistently showed negligible disparities across time.

In contrast, Mali (Supplementary: Figure 5; Supplementary: Table 5) and Malawi (Supplementary: Figure 6; Supplementary:

Table 3
Erreygers Normalized Concentration indices (ENCI) for DBM for 20 countries in SSA, various years.

Country	Year	ENCI	P-value	Robust Standard errors
Zimbabwe	2005/6	0.011	0.061	0.006
	2015	−0.003	0.524	0.004
Zambia	2007	−0.019	0.004	0.007
	2018	−0.001	0.729	0.004
Siera Leonne	2008	−0.003	0.759	0.010
	2019	−0.002	0.641	0.005
Senegal	2012/13	0.000	0.989	0.001
	2023	0.000	0.912	0.001
Mali	2006	0.000	0.915	0.003
	2018	0.006	0.054	0.003
Malawi	2004	−0.008	0.039	0.004
	2015/16	−0.007	0.124	0.004
Kenya	2008/9	−0.004	0.357	0.005
	2022	−0.000	0.959	0.001
Guinea	2005	0.003	0.472	0.004
	2018	−0.005	0.464	0.006
Ethiopia	2005	−0.004	0.331	0.004
	2019	−0.002	0.504	0.002
Burundi	2010	0.003	0.556	0.005
	2016/17	0.000	0.932	0.002
Mozambique	2011	−0.012	0.006	0.004
	2022/23	−0.004	0.258	0.003
Lesotho	2014	−0.018	0.041	0.009
	2023/24	0.000	0.972	0.008
Nigeria	2008	−0.008	0.018	0.004
	2018	−0.006	0.001	0.002
Ghana	2008	0.000	0.907	0.007
	2022	0.000	0.918	0.002
Uganda	2006	0.003	0.584	0.006
	2016	−0.000	0.989	0.003
Tanzania	2010	−0.005	0.183	0.004
	2022	−0.005	0.102	0.003
Rwanda	2010	−0.016	0.009	0.006
	2019/20	−0.012	0.011	0.005
Burkina Faso	2010	0.000	0.856	0.003
	2021	−0.002	0.454	0.002
Cameroon	2004	−0.001	0.811	0.004
	2018	−0.020	0.019	0.009
Cote d'Ivoire	2011/12	0.003	0.214	0.003
	2021	−0.001	0.789	0.003

Table 6) exhibited persistent inequalities. Mali's dominance statistic increased from 0.000 in 2006 to 0.003 in 2018, while Malawi maintained a dominance statistic of 0.001 across surveys, with fit increasing from 0.002 to 0.003. Kenya (Supplementary: Figure 7; Supplementary: Table 7) showed no inequality (dominance: 0.000), and Guinea (Supplementary: Figure 8; Supplementary: Table 8) demonstrated a decline in inequality from 2005 to 2018.

Ethiopia (Supplementary: Figure 9; Supplementary: Table 9) and Burundi (Supplementary: Figure 10; Supplementary: Table 10) displayed moderate but persistent inequality. Mozambique (Supplementary: Figure 11; Supplementary: Table 11) also showed sustained disparities (dominance: 0.001 across both years). In Lesotho (Supplementary: Figure 12; Supplementary: Table 12), inequality declined markedly from 2014 (dominance: 0.005; fit: 0.009) to 2023/24 (both: 0.000). In contrast, Nigeria (Supplementary: Figure 13; Supplementary: Table 13) saw worsening inequality, with dominance and fit rising from 0.001 in 2008 to 0.006 and 0.011, respectively, in 2018.

Ghana (Supplementary: Figure 14; Supplementary: Table 14) maintained equitable outcomes across both timepoints, while Uganda (Supplementary: Figure 15; Supplementary: Table 15) showed improvement, with moderate inequality in 2006 giving way to equality by 2016. Tanzania (Supplementary: Figure 16; Supplementary: Table 16) and Rwanda (Supplementary: Figure 17; Supplementary: Table 17) both experienced increasing disparities over time. In Burkina Faso (Supplementary: Figure 18; Supplementary: Table 18), SES-driven inequality remained minimal but rose slightly between 2010 and 2021. Cameroon (Supplementary: Figure 19; Supplementary: Table 19) and Côte d'Ivoire (Supplementary: Figure 20; Supplementary: Table 20) experienced worsening inequality, with Côte d'Ivoire's fit statistic dropping to 0.000 by 2021 despite increased curve deviation.

The results highlight substantial variation in SES-driven inequality in DBM prevalence across countries and time periods. While countries such as Zimbabwe, Zambia, and Lesotho experienced reductions in inequality, others like Nigeria, Tanzania, and Rwanda saw worsening disparities. Persistent inequalities were observed in countries such as Malawi and Ethiopia, while Kenya and Ghana maintained consistent equity over time.

3.3. Theil indices for DBM disaggregated by residence status

Table 4 presents the Theil indices for DBM, disaggregated by place of residence (urban versus rural). DBM inequality increased sharply in several countries. In Senegal, urban inequality rose from 128.56 in 2012 to 236.50 in 2023, while rural inequality surged from 247.80 to 347.00, with rural areas remaining more unequal. Similarly, Kenya experienced a rise in urban inequality from 22.88 in 2008/9 to 119.59 in 2022, and rural inequality from 19.20 to 109.29, reflecting growing disparities, particularly in urbanizing regions. In Mozambique, urban inequality increased from 13.57 in 2011 to 118.75 in 2022/23, while rural inequality rose from 11.16 to 33.70, highlighting urban disparities linked to uneven resource access. Ghana saw significant urban inequality growth from 22.30 in 2008 to 207.30 in 2022, with rural inequality increasing from 24.59 to 147.85, emphasizing widening gaps in cities. Ethiopia experienced urban inequality growth from 57.92 in 2005 to 129.10 in 2019, and rural inequality from 46.70 to 72.82, reflecting challenges in addressing urban disparities. Nigeria recorded increases in urban inequality from 12.24 in 2008 to 95.44 in 2018, and rural inequality from 10.09 to 51.61, with urban areas experiencing steeper increases. Finally, in Burundi, urban inequality rose from 37.67 in 2010 to 102.90 in 2016, and rural inequality from 25.83 to 68.72, suggesting a growing concentration of malnutrition disparities in cities.

Conversely, Guinea, Cameroon, and Côte d'Ivoire recorded significant declines in DBM inequality. In Guinea (2005–2018), urban inequality dropped from 46.13 to 18.12, and rural inequality from 53.68 to 16.48. Cameroon (2004–2018) saw urban inequality decline from 44.86 to 16.19, and rural inequality from 29.93 to 10.41. In Côte d'Ivoire (2011/12–2021), urban inequality fell from 59.58 to 42.23, and rural inequality from 126.59 to 61.65, though rural areas remain notably more unequal than urban ones.

Several countries showed much larger increases in inequality in either urban or rural areas, reflecting significant disparities in DBM. In Mozambique, urban inequality rose sharply from 13.57 in 2011 to 118.75 in 2022/23 (+105.18), while rural inequality increased more modestly, from 11.16 to 33.70 (+22.54). Similarly, Ghana recorded a larger urban increase, with the Theil index surging from 22.30 in 2008 to 207.30 in 2022 (+185.00), compared to rural inequality rising from 24.59 to 147.85 (+123.26). In Kenya, urban inequality rose from 22.88 in 2008/9 to 119.59 in 2022 (+96.71), slightly outpacing the rural increase from 19.20 to 109.29 (+90.09). These trends highlight growing DBM disparities in rapidly urbanizing areas.

Conversely, Senegal experienced a significant rise in rural inequality, increasing from 247.80 in 2012 to 347.00 in 2023 (+99.20). Urban inequality also grew, from 128.56 to 236.50 (+107.94), but the persistent disparities in rural areas remain more pronounced. These findings emphasize the need for tailored strategies to address the distinct drivers of inequality in urban and rural

Table 4
Theil indices for subgroups for DBM distinguished by place of residence.

Country	Year	Place of residence	
		Urban GE(2)[a]	Rural GE(2)[a]
Zimbabwe	2005/6	13.10	13.69
	2015	24.98	26.20
Zambia	2007	13.08	9.54
	2018	20.92	21.13
Siera Leonne	2008	11.10	12.02
	2019	24.41	28.69
Senegal	2012/13	128.56	247.80
	2023	236.50	347.00
Mali	2006	24.78	22.54
	2018	26.54	62.55
Malawi	2004	17.06	17.71
	2015/16	31.93	27.61
Kenya	2008/9	22.88	19.20
	2022	119.59	109.29
Guinea	2005	46.13	53.68
	2018	18.12	16.48
Ethiopia	2005	57.92	46.70
	2019	129.10	72.82
Burundi	2010	37.67	25.83
	2016/17	102.90	68.72
Mozambique	2011	13.57	11.16
	2022/23	118.75	33.70
Lesotho	2014	30.21	16.00
	2023/24	26.13	21.83
Nigeria	2008	12.24	10.09
	2018	95.44	51.61
Ghana	2008	22.30	24.59
	2022	207.30	147.85
Uganda	2006	37.63	27.96
	2016	65.07	38.97
Tanzania	2010	23.68	18.12
	2022	50.30	39.31
Rwanda	2010	29.80	13.41
	2019/20	27.80	26.74
Burkina Faso	2010	37.93	36.26
	2021	131.57	37.01
Cameroon	2004	44.86	29.93
	2018	16.19	10.41
Cote d'Ivoire	2011/12	59.58	126.59
	2021	42.23	61.65

[a] GE(2) represents total inequality splits into between- and within-group components.

Table 5
Theil indices for subgroups for DBM distinguished by SES.

Country	Year	Socio-economic Status		
		Poor GE(2)[a]	Middle GE(2)[a]	Rich GE(2)[a]
Zimbabwe	2005/6	15.52	12.62	10.92
	2015	25.42	21.33	45.89
Zambia	2007	9.12	10.67	17.98
	2018	20.58	21.68	21.43
Siera Leonne	2008	10.76	12.60	11.83
	2019	26.72	29.38	23.69
Senegal	2012/13	209.94	181.86	172.00
	2023	379.63	183.40	0.00
Mali	2006	24.57	20.53	28.53
	2018	64.95	41.54	32.81
Malawi	2004	15.32	19.77	19.95
	2015/16	22.49	37.11	31.26
Kenya	2008/9	18.36	20.85	23.12
	2022	104.17	128.88	108.13
Guinea	2005	62.82	38.75	79.67
	2018	16.45	16.95	18.53
Ethiopia	2005	43.64	45.89	69.36
	2019	66.34	109.29	100.92
Burundi	2010	31.57	22.87	30.07
	2016/17	79.34	57.57	109.75
Mozambique	2011	10.71	11.00	17.70
	2022/23	36.98	41.27	95.38
Lesotho	2014	13.91	22.34	33.25
	2023/24	25.03	21.83	17.20
Nigeria	2008	9.82	11.31	12.02
	2018	43.71	74.08	179.42
Ghana	2008	22.53	23.74	31.17
	2022	179.50	160.00	139.00
Uganda	2006	30.55	25.95	31.00
	2016	46.65	32.76	67.00
Tanzania	2010	17.94	18.61	23.94
	2022	39.23	37.32	72.00
Rwanda	2010	12.20	15.31	22.41
	2019/20	21.96	27.63	52.86
Burkina Faso	2010	38.97	31.01	53.73
	2021	60.31	63.22	134.50
Cameroon	2004	38.35	25.65	103.50
	2018	10.35	13.42	19.24
Cote d'Ivoire	2011/12	96.95	86.50	87.50
	2021	49.38	59.97	43.58

[a] GE(2) represent total inequality splits into between- and within-group components.

settings. Urban areas in Mozambique, Ghana, and Kenya face challenges linked to urbanization, while rural Senegal most likely struggles with entrenched disparities.

3.4. Theil indices for DBM disaggregated by SES

As shown in Table 5, several countries experienced significant changes in DBM inequality across socio-economic groups, with notable increases and decreases highlighting contrasting trends. In Kenya, DBM inequality rose sharply across all socio-economic groups from 2008/9 to 2022. The Theil index increased for the poor from 18.36 to 104.17 (+85.81), the middle group from 20.85 to 128.88 (+108.03), and the rich from 23.12 to 108.13 (+85.01). The middle group experienced the steepest rise, highlighting widening malnutrition disparities. Mozambique saw substantial inequality growth, particularly among the rich, whose Theil index jumped from 17.70 to 95.38 (+77.68) between 2011 and 2022/23. The poor and middle groups also recorded increases, with the poor rising from 10.71 to 36.98 (+26.27) and the middle group from 11.00 to 41.27 (+30.27). These trends reflect urbanization and uneven resource access. In Nigeria, inequality grew significantly from 2008 to 2018. The poor's Theil index rose from 9.82 to 43.71 (+33.89), the middle group from 11.31 to 74.08 (+62.77), and the rich from 12.02 to 179.42 (+167.40). The dramatic rise among the rich underscores widening inequities in this group. Ethiopia recorded notable increases in DBM inequality between 2005 and 2019, especially among the middle and rich groups. The Theil index rose for the poor from 43.64 to 66.34 (+22.70), the middle group from 45.89 to 109.29 (+63.40), and the rich from 69.36 to 100.92 (+31.56), with the middle group showing the largest relative rise. In Burundi, inequality worsened significantly between 2010 and 2016, particularly for the rich, whose Theil index rose from 30.07 to 109.75 (+79.68). The poor and middle groups also saw increases, with the poor rising from 31.57 to 79.34 (+47.77) and the middle group from 22.87 to 57.57 (+34.70). The largest growth among the rich highlights growing socio-economic disparities.

On the flip side, Guinea, Cameroon, and Côte d'Ivoire achieved significant reductions in DBM inequality. In Guinea (2005–2018), the Theil index declined substantially for the rich (−61.14), the poor (−46.37), and the middle group (−21.80), with the richest group seeing the largest reduction. Cameroon (2004–2018) recorded dramatic decreases, especially among the rich (−84.26), followed by the poor (−28.00) and the middle group (−12.23), reflecting notable progress in reducing disparities within wealthier populations. In Côte d'Ivoire (2011/12–2021), the Theil index fell significantly for the poor (−47.57), the rich (−43.92), and the middle group (−26.53).

Table 6
Decomposition of Theil indices by place of residence.

Country	Year		Place of residence	
		Overall inequality	$GE_B(2)$[a] [%Contribution]	$GE_w(2)$[b] [%Contribution]
Zimbabwe	2005/6	13.54	0.00 [0.00]	13.54 [100.00]
	2015	25.75	0.00 [0.00]	25.75 [100.00]
Zambia	2007	10.44	0.01 [0.10]	10.43 [99.90]
	2018	21.07	0.00 [0.00]	21.06 [100.00]
Siera Leonne	2008	11.67	0.00 [0.00]	11.67 [100.00]
	2019	27.27	0.00 [0.00]	27.27 [100.00]
Senegal	2012/13	194.81	0.05 [0.03]	194.75 [99.97]
	2023	298.00	0.02 [0.01]	297.98 [99.99]
Mali	2006	23.17	0.00 [0.00]	23.17 [100.00]
	2018	46.25	0.09 [0.19]	46.15 [99.78]
Malawi	2004	17.64	0.00 [0.00]	17.64 [100.00]
	2015/16	28.23	0.00 [0.00]	28.23 [100.00]
Kenya	2008/9	19.94	0.00 [0.00]	19.94 [100.00]
	2022	112.38	0.00 [0.00]	112.38 [100.00]
Guinea	2005	51.66	0.00 [0.00]	51.66 [100.00]
	2018	16.93	0.00 [0.00]	16.93 [100.00]
Ethiopia	2005	48.05	0.00 [0.00]	48.05 [100.00]
	2019	80.86	0.02 [0.02]	80.84 [99.99]
Burundi	2010	27.40	0.01 [0.01]	27.39 [99.96]
	2016/17	72.60	0.01 [0.01]	72.59 [99.99]
Mozambique	2011	11.86	0.00 [0.00]	11.86 [100.00]
	2022/23	43.33	0.09 [0.21]	43.24 [99.79]
Lesotho	2014	17.84	0.02 [0.11]	17.82 [99.89]
	2023/24	22.82	0.00 [0.00]	22.82 [100.00]
Nigeria	2008	10.60	0.00 [0.00]	10.60 [100.00]
	2018	62.90	0.04 [0.06]	62.86 [99.94]
Ghana	2008	23.75	0.00 [0.00]	23.75 [100.00]
	2022	167.67	0.01 [0.01]	167.65 [99.99]
Uganda	2006	28.74	0.00 [0.00]	28.74 [100.00]
	2016	41.83	0.01 [0.02]	41.82 [99.98]
Tanzania	2010	18.92	0.00 [0.00]	18.92 [100.00]
	2022	41.74	0.00 [0.00]	41.74 [100.00]
Rwanda	2010	14.52	0.02 [0.14]	14.50 [99.86]
	2019/20	26.95	0.00 [0.00]	26.95 [100.00]
Burkina Faso	2010	36.62	0.00 [0.00]	36.62 [100.00]
	2021	67.89	0.05 [0.07]	67.84 [99.93]
Cameroon	2004	34.41	0.02 [0.06]	34.39 [99.94]
	2018	12.41	0.02 [0.16]	12.39 [99.84]
Cote d'Ivoire	2011/12	91.63	0.07 [0.08]	91.56 [99.92]
	2021	52.12	0.02 [0.04]	52.10 [99.96]

[a] $GE_B(2)$ represents between-group inequality.
[b] $GE_w(2)$ represents with-in group inequality.

3.5. Decomposition analysis of theil indices by residence status and SES

As shown in Table 6, the decomposition of Theil indices by place of residence (urban and rural) reveals that within-group disparities overwhelmingly drove overall inequality in the DBM across all countries, with between-group inequalities (between rural and urban areas) contributing marginally. Across the board, GE_W accounts for nearly the entirety of overall inequality, with contributions ranging from 99.78 % to 100 %. For instance, in Zimbabwe (2005/6 and 2015), within-group inequality completely explained overall inequality, as GE_B made no contribution. Similarly, in Kenya (2008/9 and 2022), GE_W accounted for 100 % of overall inequality, with GE_B contributing nothing. In most countries, the contribution of between-group inequality (GE_B) was negligible, typically less than 0.2 %. For example, in Senegal (2023), GE_B contributed only 0.01 % to overall inequality, emphasizing that disparities between urban and rural areas were not significant compared to within-group disparities. Even in cases where GE_B had slightly higher contributions, such as Mozambique (2022/23) with 0.21 % and Rwanda (2010) with 0.14 %, within-group inequality remained the dominant driver of overall disparities. Over time, the contribution of GE_B to overall inequality showed little variation. For instance, in Nigeria, GE_B contributed 0 % in 2008 and only 0.06 % in 2018, indicating limited changes in the urban-rural disparities in inequality. Similarly, in Cameroon (2018), GE_B contributed 0.16 %, reflecting a marginal role compared to GE_W, which accounted for 99.84 % of overall inequality. This suggests that malnutrition disparities predominantly occur within rural or urban groups rather than between them.

The decomposition of Theil indices by SES highlights that within-group inequality (GE_W) overwhelmingly drives overall DBM inequality across all countries and years, consistently contributing over 99 % (Table 7). For example, in Zimbabwe (2005/6 and 2015), GE_W, accounted for 99.93 % and 99.88 %, respectively, while Zambia (2007 and 2018) and Kenya (2008/9 and 2022) showed GE_W contributions of 99.90 %–100 %. Between-group inequality (GE_B) contributions are negligible, with rare exceptions like Lesotho (2014) and Cameroon (2004), where GE_B reached 0.22 % and 0.17 %, respectively. These findings emphasize that reducing DBM disparities within socio-economic groups is key to addressing overall inequality in Sub-Saharan Africa.

4. Discussion

The temporal trends in the double burden of malnutrition across 20 Sub-Saharan African countries reveal significant progress in reducing overall stunting, wasting, overweight, underweight, and

Table 7
decomposition of theil indices by SES.

Country	Year		SES	
		Overall inequality	$GE_B(2)$ [a][%Contribution]	$GE_w(2)$ [b][%Contribution]
Zimbabwe	2005/6	13.54	0.01 [0.07]	13.53 [99.93]
	2015	25.75	0.03 [0.12]	25.73 [99.88]
Zambia	2007	10.44	0.01 [0.10]	10.43 [99.90]
	2018	21.07	0.00 [0.00]	21.07 [100.00]
Siera Leonne	2008	11.67	0.00 [0.00]	11.67 [100.00]
	2019	27.28	0.00 [0.00]	27.28 [100.00]
Senegal	2012/13	194.80	0.00 [0.00]	194.80 [100.00]
	2023	298.00	0.13 [0.04]	297.87 [99.96]
Mali	2006	23.17	0.01 [0.04]	23.16 [99.96]
	2018	46.25	0.03 [0.06]	46.21 [99.94]
Malawi	2004	17.64	0.01 [0.06]	17.64 [99.94]
	2015/16	28.23	0.03 [0.11]	28.20 [99.89]
Kenya	2008/9	19.94	0.00 [0.00]	19.94 [100.00]
	2022	112.38	0.00 [0.00]	112.38 [100.00]
Guinea	2005	51.67	0.04 [0.08]	51.63 [99.92]
	2018	16.93	0.00 [0.00]	16.93 [100.00]
Ethiopia	2005	48.05	0.01 [0.02]	48.04 [99.98]
	2019	80.86	0.03 [0.04]	80.83 [99.96]
Burundi	2010	27.40	0.01 [0.04]	27.39 [99.96]
	2016/17	72.60	0.03 [0.04]	72.58 [99.96]
Mozambique	2011	11.86	0.01 [0.08]	11.85 [99.92]
	2022/23	43.33	0.03 [0.07]	43.30 [99.93]
Lesotho	2014	17.84	0.04 [0.22]	17.80 [99.78]
	2023/24	22.81	0.01 [0.04]	22.81 [99.96]
Nigeria	2008	10.60	0.00 [0.00]	10.60 [100.00]
	2018	62.90	0.08 [0.13]	62.82 [99.87]
Ghana	2008	23.75	0.00 [0.00]	23.75 [100.00]
	2022	167.66	0.00 [0.00]	167.66 [100.00]
Uganda	2006	28.74	0.00 [0.00]	28.74 [100.00]
	2016	41.83	0.03 [0.07]	41.80 [99.93]
Tanzania	2010	18.92	0.00 [0.00]	18.92 [100.00]
	2022	41.74	0.02 [0.05]	41.72 [99.95]
Rwanda	2010	14.52	0.02 [0.14]	14.51 [99.93]
	2019/20	26.95	0.03 [0.11]	26.92 [99.89]
Burkina Faso	2010	36.62	0.02 [0.05]	36.61 [99.97]
	2021	67.89	0.02 [0.03]	67.86 [99.96]
Cameroon	2004	34.41	0.06 [0.17]	34.35 [99.83]
	2018	12.41	0.02 [0.16]	12.40 [99.92]
Cote d'Ivoire	2011/12	91.63	0.00 [0.00]	91.63 [100.00]
	2021	52.12	0.00 [0.00]	52.12 [100.00]

[a] $GE_B(2)$ represents between-group inequality.
[b] $GE_w(2)$ represents with-in group inequality.

DBM rates in several countries. However, these gains are uneven, with substantial socioeconomic and residential disparities persisting or worsening over time. While some countries show reductions in individual-level DBM inequality, others have experienced increases, particularly in urban areas and among wealthier groups, highlighting the evolving nature of malnutrition challenges in SSA.

Our study results showed rising concentration of DBM among wealthier households, particularly in countries such as Kenya, Burkina Faso, Mozambique, Nigeria and Ethiopia, reflecting a broader nutrition transition occurring in LMICs. This shift, characterized by the increasing adoption of Westernized diets high in energy-dense, nutrient-poor foods, is consistent with global trends observed in other LMICs [58]. Economic growth often results in greater access to such foods, leading to rising obesity rates among children in wealthier families, while undernutrition continues to affect poorer populations who struggle with limited access to adequate healthcare and nutritious foods [47]. These socioeconomic disparities align with previous research that emphasizes the challenges of addressing malnutrition in LMICs undergoing rapid economic and social transitions [5,59]. The persistence of undernutrition in lower-income groups, despite economic progress, underscores the need for targeted public health interventions that address both forms of malnutrition simultaneously, focusing on child nutrition in particular [4].

The findings also revealed that DBM inequalities were more pronounced in rural areas compared to urban regions, particularly among under-five children in countries like Senegal and Mali. This is consistent with studies showing that rural populations face substantial challenges in addressing both undernutrition and rising overnutrition among young children due to limited healthcare access, poor infrastructure, and lower educational attainment [25,48]. Rural under-five children are particularly vulnerable to these inequalities, as they are in a critical phase of growth and development and are more severely affected by both forms of malnutrition [60–64].

The temporal analysis revealed significant increases in DBM inequalities over time in most countries with large increases observed in Kenya, Ghana, Nigeria, Mozambique, Burundi, and Zimbabwe, where both under- and overnutrition became more pronounced. Economic growth and rapid urbanization in low-middle income countries have led to a complex scenario where wealthier populations experience a rise in obesity among children due to changes in dietary patterns, while poorer households still struggle with high levels of undernutrition, particularly stunting and wasting [65,66]. As wealthier households adopt Westernized

diets high in fats, sugars, and processed foods, obesity becomes more prevalent, while poorer households continue to struggle with food insecurity and undernutrition [4]. In Kenya, the rise in obesity rates among higher-income groups has coincided with persistent stunting and wasting among lower-income households, largely driven by unequal access to nutritious foods and healthcare services [24,67].

In contrast, countries such as Guinea, Cameroon and Côte d'Ivoire have made notable progress in reducing DBM inequalities among under-five children. Guinea, for instance, has seen reductions in stunting and wasting, particularly through nutrition-sensitive interventions focused on maternal and child health, food security, and education [68]. These cases highlight that focused and sustained public health efforts can have a significant impact on mitigating DBM among young children, even in countries with limited resources. As evident in our study findings the divergent trends between countries such as Kenya and Zimbabwe (where DBM inequalities are increasing) and Guinea and Cameroon (where malnutrition disparities are improving) underscore the importance of context-specific interventions. Economic development alone does not lead to better nutrition outcomes for children. Instead, targeted policies that address both the root causes of undernutrition (such as poverty and food insecurity) and the rising trend of overnutrition (linked to sedentary lifestyles and processed food consumption) are needed to ensure that all children benefit from socio-economic progress [29,69].

The decomposition analysis underscores that within-group disparities in rural and urban areas, are the significant drivers of DBM inequality among under-five children. Inequalities within urban areas are the primary contributors to overall DBM inequality in Mozambique, Ghana, Kenya, Burundi, Burkina Faso, and Nigeria. In contrast, within-group rural disparities are the main drivers of DBM inequality in Senegal and Mali. This suggests that the primary issue is not the differences between urban and rural populations, but rather the pronounced inequalities within urban and rural areas. Urban settings often exhibit significant heterogeneity, with high-income populations living alongside those in informal settlements, resulting in stark inequalities in access to nutrition, healthcare, and other resources. In rural areas where children from poorer households are disproportionately affected by stunting, wasting, and other forms of undernutrition, while adults may experience rising rates of overnutrition [70–74]. In rural regions, under-five children face multiple barriers, including food insecurity, inadequate healthcare, and limited access to early childhood nutrition programs [75,76]. These disparities are exacerbated in wealthier rural households, where overweight or obese parents may still have children who suffer from undernutrition [77]. The paradox of rising obesity in rural adults and persistent undernutrition among young children illustrates how within-group SES disparities are particularly detrimental to under-five children, whose nutritional needs are often unmet despite overall improvements in household income.

The decomposition analysis also demonstrates that inequalities within SES groups are significant drivers of overall DBM inequality across Sub-Saharan Africa, with notable variations in the roles of the poor, middle, and rich subgroups depending on the country. In several countries, inequalities within the richest SES group are the predominant drivers of overall DBM inequality. For instance, in Nigeria, Mozambique, and Burundi, disparities within the wealthiest populations are particularly striking. These findings suggest that even among those with greater economic resources, inequities in access to nutrition, healthcare, or other determinants of health persist. Such within-group disparities among the rich may reflect unequal distribution of wealth or differences in lifestyle and diet that exacerbate malnutrition [78,79]. Conversely, in countries such as Senegal and Mali, inequalities within the poorest SES group contribute most significantly to DBM inequality. The substantial disparities among poorer populations in these countries likely reflect the persistent challenges of food insecurity, inadequate healthcare access, and broader structural inequities [80,81]. In some countries, such as Kenya and Ethiopia, the middle SES group exhibits the highest levels of inequality. This suggests that inequalities are not confined to the extremes of wealth and poverty but are also pronounced among middle-income populations. This may reflect a transitional phase where economic growth has created new disparities within the middle class, potentially due to unequal access to emerging opportunities or the uneven benefits of development [78].

To address these disparities in DBM among under-five children, public health interventions must be tailored to the specific needs of residence and SES groups. Rural communities and disadvantaged urban populations require improved healthcare infrastructure, access to diverse and nutritious foods, and targeted early childhood nutrition programs [75,82]. This is especially important in combating undernutrition among under-five children, who are most vulnerable to its lifelong consequences. Enhancing transportation networks to improve food distribution, supporting local agriculture to increase the availability of nutrient-dense foods, and investing in early intervention healthcare programs are crucial steps in addressing the root causes of undernutrition in rural areas [83].

Furthermore, SES-based interventions are essential for reducing malnutrition disparities among under-five children. Programs that focus on improving food security, maternal and child health, and education for the poorest households can significantly improve nutritional outcomes for young children [84]. Social safety nets, such as school feeding programs and maternal-child health services, can help address the specific nutritional needs of under-five children in lower SES groups. Countries like Guinea, Cameroon and Côte d'Ivoire, which have seen reductions in SES-based DBM inequalities, demonstrate that targeted nutrition-sensitive interventions can help mitigate the effects of both under- and overnutrition in young children [47]. In wealthier rural households, efforts should be made to raise awareness of the risks of overnutrition, particularly in adults, and promote healthier dietary choices for under-five children. Comprehensive public health policies that target both forms of malnutrition must prioritize the nutritional needs of young children to prevent the long-term developmental and health issues associated with DBM.

4.1. Strengths and limitations

This study has several strengths. First, it utilizes nationally representative datasets from the Demographic and Health Surveys (DHS) [49], which are high-quality and standardized across multiple countries, ensuring the findings are robust and generalizable to broader populations in Sub-Saharan Africa. The focus on children under five, a critical developmental period, allows for understanding of malnutrition during early childhood, which is crucial for long-term growth, cognitive development, and overall health [71,85–87]. Additionally, by addressing both undernutrition (stunting, wasting, and underweight) and overnutrition (overweight), the study captured the dual burden of malnutrition, reflecting the growing complexity of nutrition challenges in economically transitioning regions. The inclusion of twenty Sub-Saharan African countries, combined with temporal analysis, offers a valuable perspective on trends over time and enables the identification of within- and between-group disparities. Moreover, the application of Erreygers Normalized Concentration Indices and Theil indices offers a robust framework for assessing inequalities,

enabling a comprehensive decomposition of socio-economic and geographical disparities in DBM. This study, therefore, furthers a methodological approach that can be adapted to measure progress in other health indicators, fostering a deeper understanding of inequality dynamics across various contexts. Okova et al. applied as similar approach to examine progress in malaria prevention among pregnant women and children under-five in SSA [88].

However, the study also has several limitations. A primary limitation is the cross-sectional nature of the DHS data, which restricts the ability to infer causal relationships between socio-economic status, residence, and DBM among under-five children. While temporal trends can be observed between different survey periods, individual-level changes over time cannot be tracked. Additionally, the wealth index used to assess socio-economic status, though widely applied, is a relative measure and may not fully capture the nuances of income, education, or access to resources across different countries, potentially affecting cross-country comparisons [52,89]. Furthermore, while the study focuses on key anthropometric measures (stunting, wasting, underweight, and overweight), it does not capture other important dimensions of malnutrition, such as micronutrient deficiencies or dietary diversity, which limits the comprehensive understanding of the nutritional landscape in these countries. Lastly, although urban-rural disparities are a focus, the study may underestimate within-urban inequalities, particularly those related to informal settlements or slums, where malnutrition rates among under-five children may be disproportionately high. This could lead to an incomplete picture of malnutrition disparities in urban settings.

5. Conclusion

This study sheds light on the complex and evolving challenge of the double burden of malnutrition among under-five children in Sub-Saharan Africa, with a specific focus on temporal socio-economic inequalities. The findings underscore that individual-level DBM is increasingly concentrated among wealthier households, particularly in countries like Kenya and Ethiopia, due to the nutrition transition driven by economic growth, urbanization, and the adoption of Westernized diets. At the same time, undernutrition remains a critical issue among poorer households, highlighting the persistent disparities in access to nutritious food and healthcare. The decomposition analysis revealed that within-group disparities, particularly among rural and lower socio-economic status populations, are the primary drivers of DBM inequality. This is particularly concerning for young children, as undernutrition during early childhood can lead to lifelong developmental and health challenges. Overall, the study highlights that economic development alone is insufficient to address the dual burden of malnutrition in Sub-Saharan Africa. It calls for targeted, contextually informed public health strategies that prioritize the nutritional needs of under-five children, especially those from the most vulnerable socio-economic groups, to ensure more equitable health outcomes across the region. Methodologically, this study showcases the implementation of a robust framework for evaluating progress in public health, providing a reliable approach for analyzing and addressing key public health challenges.

CRediT authorship contribution statement

Akim Tafadzwa Lukwa: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Denis Okova:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Paidamoyo Bodzo:** Writing – review & editing, Writing – original draft. **Sikelela Charles Maseko:** Writing – review & editing, Writing – original draft. **Melisa Bhebe:** Writing – review & editing, Writing – original draft. **Folahanmi Tomiwa Akinsolu:** Writing – review & editing, Writing – original draft. **Abodunrin Olunike:** Writing – review & editing, Writing – original draft. **Emmanuella Nzeribe:** Writing – review & editing, Writing – original draft. **Aggrey Siya:** Writing – review & editing, Writing – original draft. **Admire Nyabunze:** Writing – review & editing, Writing – original draft. **Charles Hongoro:** Writing – review & editing, Writing – original draft, Supervision. **Plaxcedes Chiwire:** Writing – review & editing, Writing – original draft, Supervision.

Consent for publication

All authors have reviewed and consented to the publication of this manuscript.

Availability of data and materials

Datasets are available at http://www.dhsprogram.com.

Ethics

This study did not require separate ethical approval as it was based on publicly available data from the Demographic and Health Surveys (DHS) program. The datasets used are accessible on the DHS website (http://www.dhsprogram.com), and all data collection procedures for the parent studies were approved by the relevant ethical review boards in the respective countries. The DHS program ensures that data collection is conducted in accordance with ethical standards, including obtaining informed consent from participants. Researchers can request access to the data directly from the DHS program.

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Declaration of competing interest

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Appendix A. Supplementary data

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