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Triple burden of malnutrition among mother-child pairs in low and middle-income countries: In the era of sustainable development goals

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Abstract

Objective: This study aimed to assess the prevalence and determinants of the triple burden of malnutrition among mother-child pairs in low-and middle-income countries.

Design: Cross-Sectional Study

Setting: Low-and middle-income countries

Participants: Women and children

Primary outcome: Triple burden of malnutrition

Methods: Data for this study were drawn from recent 22 low and middle-income countries Demographic and Health Surveys (DHSs). A total weighted sample of 116,795 mother-child pairs was included in the study. STATA version 14.2 was used to clean, code and analyze the data. Multilevel logistic regression was employed to identify factors associated with the problem. Adjusted odds ratio with 95% CI and a P value <0.05 was reported to indicate statistical association. Model fitness and comparison were done using ICC, MOR, PCV, and deviance.

Result: The pooled prevalence of the triple burden of malnutrition among mother-child pairs was 11.39%. It showed statistically significant positive associations with mothers aged ≥35 years (AOR=2.25,95%CI 2.08-2.44), family size >10 (AOR=1.17,95%CI 1.08-1.26), delivery by CS (AOR=1.93,95%CI 1.83-2.03), the richest household (AOR=1.72,95%CI 1.56-1.88), grand multiparous (AOR=1.62, 95% CI 1.46-1.81), age of child 36-47 months (AOR=1.77, 95% CI 1.64-1.90), at a p-value of <0.05. Whereas breastfeeding (AOR=0.94,95%CI 0.89-0.99), married mothers (AOR=0.87,95%CI 0.78-0.96), female children (AOR=0.88,95%CI 0.84-0.92), improved toilet (AOR=0.23,95%CI 0.17-0.29), improved source of drinking water (AOR=0.28,95%CI 0.21-0.35), rural residents (AOR=0.66,95%CI 0.62-0.69) had a contrasting relationship with the triple burden of malnutrition

Conclusions: About 1 out of 10 households suffer from the triple burden of malnutrition in low and middle-income countries. This study revealed that several maternal, child, household, and community-level factors have a significant impact on the triple burden of malnutrition among mother-child pairs. Prevention of the problem requires collective efforts from the governments, the scientific and medical communities, and the industry towards changing dietary and lifestyle habits.

Keywords: Triple burden, mother-child pairs, malnutrition, low and middle-income countries.

Strengths and limitations of this study

- The findings were supported by large datasets covering 22 LMICs.
- We employed multilevel analysis which is an appropriate methodology for such data
- The data were collected using a common internationally acceptable methodological procedure.
- DHS used a cross-sectional survey design, and the causal relationship between the triple burden of malnutrition and the independent variables cannot be established.
- We didn't include important covariates such as dietary intake, physical activity level, or comorbidities as the DHS did not collect information on these variables

Background

The triple burden of malnutrition, defined as the coexistence of overnutrition, undernutrition, and micronutrient deficiencies is increasing in low and middle-income countries (LMICs) (1). The World Health Organization (WHO) characterized overnutrition (Obesity and overweight) as a pandemia of a major public health concern due to the increased frequency of the problem in many countries (2). It is ranked as the sixth leading cause of disability-adjusted life years (DALYs) and accounts for approximately 4 million people dying each year worldwide (3-5). Several previous studies have shown, following marked dietary change that obesity/overweight is increasing more rapidly in low and middle-income countries compared to higher-income countries (6, 7).

Similarly, undernutrition continues to be a major public health concern throughout the developing world (8, 9). Nearly half of all deaths in children under 5 are attributable to undernutrition and it encompasses wasting, stunting, underweight, and micronutrient deficiencies (anemia) (10, 11). Despite stunting having declined steadily, faster progress is needed to reach the 2030 target (12, 13). Wasting and underweight persisting at alarming rates require a reversal in trajectory if the 2030 target is to be achieved (14). Since 2000, a significant reduction in the prevalence of anemia in children under five has been observed in many low- and lower-middle-income countries (15). Children are more vulnerable to inadequate pre-natal, infant, and young child nutrition, particularly in resource-constrained settings (16, 17). Endorsing early childhood feeding best practices is crucial to improve the health of children (18).

Malnutrition has a tremendous negative impact on the normal functioning of every organ system (19). It can cause permanent, widespread damage to a child's growth, development, and well-being (20). Scientific evidence has shown that malnutrition in children is associated with poorer school performance, increased susceptibility to infections, and slow recovery from illness (21, 22).

Maternal malnutrition increases the risk of poor pregnancy outcomes including obstructed labor, premature or low-birth-weight babies, and postpartum hemorrhage (23, 24). To reduce the problem the United Nations (UN) adopted the Sustainable Development Goals (SDGs), especially those targeted to end poverty in all its forms everywhere (SDG 1), end hunger, achieve food security, improve nutrition, promote sustainable agriculture (SDG 2), ensure healthy lives, and promote well-being for all at all ages (SDG 3) (25, 26).

Previous literature recognizes the basic and underlying causes of malnutrition including the environmental, economic, and sociopolitical contextual factors, with poverty having a central role (11, 27-29). Given the persistent and high levels of triple burden of malnutrition among mother-child pairs in low and middle-income countries, there is a strong need for action. To design and deliver effective interventions adequate understanding of the socioeconomic, environmental, and cultural factors is highly important. Besides if the SDG targets are to be met, coordinated action is required toward not only sustaining current rates of decline but also accelerating progress. Therefore, the objective of this study was to assess the prevalence of the triple burden of malnutrition among mothers and children and the potential factors associated with it in low and middle-income countries.

Materials and methods

Study design, setting, and period

The present study is based on 22 low and middle-income countries that have had Demographic and Health Surveys (DHS) since 2016. The DHS used a cross-sectional survey study design to collect data and provide population and health indicators at the national level. The list of those countries and the respective year of surveys is provided in Table 1.

Table 1. Study setting and year of surveys

Country	Year of survey	Region
Albania	2017/18	Southeastern Europe
Benin	2017/18	West Africa
Burundi	2016/17	East-central Africa
Cameroon	2018	West-central Africa
Ethiopia	2016	East Africa
Gambia	2019/20	West Africa
Guinea	2018	West Africa
Haiti	2016/17	Caribbean
India	2019/21	South Asia
Liberia	2019/20	West Africa
Madagascar	2021	East Africa
Mali	2018	West Africa
Mauritania	2019/21	Northwest Africa
Maldives	2016/17	South Asia
Nigeria	2018	West Africa
Nepal	2016	South Asia
Rwanda	2019/20	East Africa
Sierra Leone	2019	West Africa
Tajikistan	2017	Central Asia
Timor Leste	2016	South Asia
Uganda	2016	East Africa
South Africa	2016	South Africa

Data source and sampling procedure

The current analyses was based on pooled data from DHSs in 22 LMICs. These are nationally representative surveys that collect data on reproductive, maternal, neonatal, child health, and nutrition in LMIC. The surveys are similarly designed that used standardized questionnaires and data collection procedures, allowing therefore comparability of results. The survey employed a two-stage cluster sampling technique. In the first stage, the selection of proportional clusters/enumeration areas was performed using each country's most recent population and housing census as a sampling frame. In the second stage, a systematic selection of households from the newly created cluster was performed. A detailed description of the DHS sampling design and

data collection procedures has been found in each country's DHS report. The study population for this study was mother-child pairs.

Definition of variables

Outcome variable:

The triple burden of malnutrition was the outcome variable of this study where the mother was overweight/obese and children under 5 years of age were undernourished and anemic. At the same household level, first, we created four different categories of malnutrition such as overweight/obese mother and stunted child, overweight/obese mother and wasted child, overweight/obese mother and underweight child, and overweight/obese mother and anemic child. Then we further combined overweight/obese mothers, undernourished children, and anemic children to generate the triple burden of malnutrition.

Independent variables:

Based on previous works of literature and the likelihood of influencing the outcome of interest, several explanatory variables including the age of mothers, mother's education, marital status, current breastfeeding, delivery by cesarean section, family size, wealth index, media access, parity, age of the child, sex of the child, type of toilet facility, source of drinking water, residence and distance to health facility were considered.

Statistical analyses

We append the dataset of each country to generate pooled data. The data extraction, coding, and analysis were carried out using STATA software version 14.2. We weighted the sample to restore the representativeness of the sample so that the total sample looks like the country's actual population. Due to the hierarchical nature of the DHS, the multilevel analysis was fitted to identify significantly associated factors. Four models were fitted; the null model (with no predictors), the

model I (adjusted for individual-level variables only), model II (adjusted for community-level variables only), and model III (model adjustment for both individual and community-level variables simultaneously). Adjusted OR (AOR) with 95% CI and $p<0.05$ were used to determine significant predictors. Model fitness and comparison were done using Intraclass Correlation Coefficient (ICC), Proportional Change in Variance (PCV), Median Odds Ratio (MOR), the Likelihood Ratio test (LR), and deviance computed.

Patient and public involvement statement

As our study used secondary analysis of DHS data, participants and the public were not involved in the study design or planning of the study. The study participants were not consulted to interpret the results and write or editing of this document for readability or accuracy.

Results

A total of 116,795 mother-child pairs were included in the study. Over half (56.48%) of mothers were in the age category of 25-34 years. About 22.98% of mothers were illiterate and the majority (46.39%) had attended secondary education. Approximately 95.73% of mothers were married and 62.89% were currently breastfeeding. About 20.33% and 21.21% of the households were in the low wealth quintile of poorest and poorer respectively. Over a quarter (27.62%) of the families had never been exposed to any type of media. The majority of the children (32.59%) were aged ≤12 months. A large proportion (83.60%) of the households had improved sources of drinking water and almost two-thirds (67.02%) of the households had improved toilet facilities. Almost three fourth (71.03%) of participants lived in rural areas and for over a quarter (27.42%) of those participants, the distance to access health facilities was a big problem (**Table 2**).

Table 2. Socio-demographic characteristics of the study participants

Variables	Categories	Unweighted frequency (%)	Weighted frequency (%)
Age of mothers	15-24	34,983 (29.05)	35,918 (30.75)
	25-34	68,386 (56.78)	65,971 (56.48)
	≥35	17,073 (14.18)	14,906 (12.76)
Mothers education	No education	27,995 (23.24)	26,845 (22.98)
	Primary education	19,684 (16.34)	18,633 (15.95)
	Secondary	57,008 (47.33)	54,185 (46.39)
	Higher	15,755 (13.08)	17,131 (14.67)
Mothers marital status	Not in union	5,583 (4.64)	4,987 (4.27)
	Married	114,859 (95.36)	111,807 (95.73)
Currently breastfeeding	No	44,160 (36.66)	43,338 (37.11)
	Yes	76,282 (63.34)	73,457 (62.89)
Delivery by cesarean section	No	99,291 (82.49)	93,974 (80.51)
	Yes	21,077 (17.51)	22,748 (19.49)
Family size	≤5	56,365 (46.80)	53,677 (45.96)
	6-10	54,605 (45.34)	53,258 (45.60)
	>10	9,472 (7.86)	9,859 (8.44)
Wealth index	Poorest	28,097 (23.33)	23,749 (20.33)
	Poorer	27,352 (22.71)	24,774 (21.21)
	Middle	24,741 (20.54)	24,330 (20.83)
	Richer	22,180 (18.42)	23,880 (20.45)
	Richest	18,072 (15.00)	20,061 (17.18)
Media access	No	33,942 (28.18)	32,256 (27.62)
	Yes	86,500 (71.82)	84,539 (72.38)
Parity	Primiparous	36,241 (30.09)	35,333 (30.25)
	Multiparous	76,092 (63.18)	73,823 (63.21)
	Grand Multiparous	8,109 (6.73)	7,639 (6.54)
Age of child	≤12	38,959 (32.35)	38,059 (32.59)
	13-23	25,382 (21.07)	24,819 (21.25)
	24-35	22,208 (18.44)	21,478 (18.39)
	36-47	17,948 (14.90)	17,204 (14.73)
	48-59	15,945 (13.24)	15,234 (13.04)
Sex of child	Male	63,660 (52.86)	62,008 (53.09)
	Female	56,782 (47.14)	54,787 (46.91)
Type of toilet facility	Unimproved	37,519 (31.15)	38,518 (32.98)
	Improved	82,923 (68.85)	78,277 (67.02)
Source of drinking water	Unimproved	20,959 (17.40)	19,159 (16.40)
	Improved	99,483 (82.60)	97,636 (83.60)
Residence	Urban	28,722 (23.85)	33,838 (28.97)
	Rural	91,720 (76.15)	82,957 (71.03)
Distance to health facility	No problem	84,605 (70.25)	84,776 (72.58)
	Big problem	35,837 (29.75)	32,019 (27.42)

Prevalence of triple burden of malnutrition

In 22 low and middle-income countries, the pooled prevalence of the triple burden of malnutrition among mother-child pairs was found at 11.39 % (95% CI 9.56%, 13.23%). Ethiopia has the lowest (3.54 %) prevalence of triple burden while Mauritania (31.66%) bears the highest (**Figure 1**).

Fig 1. The pooled prevalence of the triple burden of malnutrition

Multilevel analyses

Random parameter estimation and model selection

Based on the result of random effect analysis, the ICC of the null model was 0.30, indicating that 30% of the total variability in triple burden prevalence was attributable to between-cluster variability, while about 70% was due to individual differences. The null model MOR was 3.04, which indicates that a mother/child from a cluster with a high triple burden prevalence has a 3.04 times higher probability of being malnourished than a mother/child from a cluster with a lower prevalence. Model III was the best-fitted model since it has the highest log likelihood (-91665) and the lowest deviance (183,330) value **(Table 3)**.

Factors associated with the triple burden of malnutrition (Fixed effects)

The existence of triple burden of malnutrition showed statistically significant positive associations with mothers aged 25-34 years (AOR=1.54, 95% CI 1.45 - 1.63), ≥35 years (AOR=2.25, 95% CI 2.08 - 2.44), mothers attended secondary education (AOR=1.08, 95% CI 1.02-1.15), family size >10 (AOR=1.17, 95% CI 1.08 - 1.26), delivery by CS (AOR=1.93, 95% CI 1.83 - 2.03), the richer household (AOR=1.63, 95% CI 1.49 - 1.76), the richest household (AOR=1.72, 95% CI 1.56 - 1.88), multiparous (AOR=1.42, 95% CI 1.34 - 1.49), grand multiparous (AOR=1.62, 95% CI 1.46 - 1.81), age of child 36-47 months (AOR=1.77, 95% CI 1.64 - 1.90), age of child 48-59 (AOR=1.51, 95% CI 1.39 - 1.64), at a p-value of <0·05. Whereas breastfeeding (AOR=0.94, 95%

198 CI 0.89 - 0.99), married mothers (AOR=0.87, 95% CI 0.78 - 0.96), female children (AOR=0.88,
199 95% CI 0.84 - 0.92), improved toilet facility (AOR=0.23, 95% CI 0.17 - 0.29), improved source
200 of drinking water (AOR=0.28, 95% CI 0.21 - 0.35), rural residents (AOR=0.66, 95% CI 0.62 -
201 0.69) showed a contrasting relationship with the triple burden of malnutrition **(Table 3)**.

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203 Table 3. Multivariable multilevel logistic regression analysis of the triple burden of malnutrition.

Variables	Categories	Null model	Model I AOR 95% CI	Model II AOR 95% CI	Model III AOR 95% CI
Age of mothers	15-24		1.00		1.00
	25-34		1.54 (1.46 - 1.63)**	—	1.54 (1.45 - 1.63)**
	≥35		2.28 (2.11 - 2.47)**	—	2.25 (2.08 - 2.44)**
Mothers education	No education		1.00		1.00
	Primary education		1.04 (0.97 - 1.12)	—	1.04 (0.97 - 1.12)
	Secondary		1.08 (1.01 - 1.15)*	—	1.08 (1.02 - 1.15)*
	Higher		0.94 (0.86 - 1.02)	—	0.94 (0.86 - 1.02)
Mothers marital status	Not in union		1.00		1.00
	Married		0.83 (0.75 - 0.93)*	—	0.87 (0.78 - 0.96)**
Currently breast feeding	No		1.00		1.00
	Yes		0.92 (0.87 - 0.97)*	—	0.94 (0.89 - 0.99)*
Delivery by CS	No		1.00		1.00
	Yes		1.94 (1.84 - 2.04)**	—	1.93 (1.83 - 2.03)**
Family size	≤5		1.00		1.00
	6-10		1.00 (0.97 - 1.08)	—	1.01 (0.98 - 1.08)
	>10		1.14 (1.06 - 1.24)**	—	1.17 (1.08 - 1.26)**
Wealth index	Poorest		1.00		1.00
	Poorer		1.41 (1.31 - 1.52)**	—	1.38 (1.28 - 1.49)**
	Middle		1.60 (1.48 - 1.73)**	—	1.49 (1.38 - 1.62)**
	Richer		1.86 (1.72 - 2.02)**	—	1.63 (1.49 - 1.76)**
	Richest		2.15 (1.97 - 2.35)**	—	1.72 (1.56 - 1.88)**
Media access	No		1.00		1.00
	Yes		1.01 (0.98 - 1.08)	—	1.02 (0.99 - 1.11)
Parity	Primiparous		1.00		1.00
	Multiparous		1.42 (1.34 - 1.50)**	—	1.42 (1.34 - 1.49)**
	Grand Multiparous		1.61 (1.44 - 1.79)**	—	1.62 (1.46 - 1.81)**
Age of child	≤12		1.00		1.00
	13-23		1.41 (1.32 - 1.50)**	—	1.41 (1.32 - 1.50)**
	24-35		1.62 (1.52 - 1.73)**	—	1.63 (1.53 - 1.74)**
	36-47		1.75 (1.62 - 1.89)**	—	1.77 (1.64 - 1.90)**
	48-59		1.50 (1.38 - 1.62)**	—	1.51 (1.39 - 1.64)**

Sex of child	Male		1.00		1.00
	Female		0.88 (0.84 - 0.92)**	—	0.88 (0.84 - 0.92)**
Type of toilet facility	Unimproved		1.00		1.00
	Improved		0.24 (0.18 - 1.31)	—	0.23 (0.17 - 0.29)**
Source of drinking water	Unimproved		1.00		1.00
	Improved		0.21 (0.16 - 0.28)	—	0.28 (0.21 - 0.35)**
Community-level variables					
Residence	Urban			1.00	1.00
	Rural		—	0.49 (0.46 - 0.52)**	0.66 (0.62 - 0.69)**
Distance to health facility	No problem			1.00	1.00
	Big problem		—	0.87 (0.82 - 0.91)**	0.94 (0.89 - 0.98)**
Random effect					
	Variance	1.40	1.24	1.31	1.23
	ICC	0.30	0.27	0.28	0.27
	MOR	3.04	2.88	2.96	2.85
	PCV	Reff	11.42	6.43	12.14
Model comparison					
	Log likelihood ratio	-100585	-92108	-97815	-91665
	Deviance	201,170	184,216	195,630	183,330

* = P-value < 0.05, ** = P-value < 0.01,
ICC = Inter cluster correlation coefficient, MOR =Median odds ratio, PCV = proportional change in variance. AOR=adjusted odds ratio; CI= confidence interval,

Discussion

Low and middle-income countries are increasingly facing the triple burden of malnutrition where women and children are among the hardest hit by the burden (30, 31). The present study examined the co-occurrence of undernutrition, overweight/obesity, and anemia among mother-child pairs in the same household using nationally representative data. The finding showed that the prevalence of triple burden found at 11.39 % (95% CI 9.56%, 13.23%), Ethiopia has the lowest (3.54 %) prevalence while Mauritania (31.66%) bears the highest. The variation among countries could be attributed to differences in socio-economic status, food environment, physical activity, genetic factors, health care system strength, national policy, and political commitments.

This study revealed that several maternal, child, household, and community-level factors have a significant impact on the triple burden of malnutrition among mother-child pairs. It has found a

parallel correlation between the triple burden of malnutrition and maternal age. The odds of being malnourished increase as the age of the mother increases where older mothers bear the highest risk compared to younger ones. Various findings (32, 33) have revealed that older women have an increased risk of malnutrition, this could be because of reduced physical activity, less energy requirement, and hormonal changes. Similarly, mothers who attended secondary education were more likely to be malnourished (33). A plausible explanation for this could be the shifts from manual labor to more sedentary occupations and the related decline in physical activity.

Being married reduced the risk of the triple burden of malnutrition. Partners together could generate more money, reduce food insecurity, and tend to take better care of themselves and their children. It is been reported that children in single-parent households suffered from undernutrition significantly more than children brought up by both parents (34, 35). Likewise, this study revealed breastfeeding reduced the triple burden of malnutrition. Breastfeeding plays a vital role in the prevention of different forms of childhood malnutrition (36). Delivery by cesarean section (C-section) delays the timely initiation of breastfeeding and prelacteal feeding (37). Previous studies have reported that C-section increases maternal obesity and negatively affects the breastfeeding of children, which results suffer from malnutrition (38, 39). Moreover, malnutrition in children is related to gut microbiota alteration and C-section contributes to microbial alterations in the small intestine (40).

Our study revealed a parallel relationship between the household wealth quintiles and the triple burden of malnutrition. As household income increases, the odds of malnutrition increase (41, 42). High income could increase the purchasing power for food, influencing the type of foods consumed and the intake of prepared or processed food (30). Economic growth and the food industry's rapid penetration into the market have resulted in diets based on energy-dense and

nutrient-poor foods (43). In recent years, the dietary preference in LMICs has changed as the food environment is dominated by media advertising and relatively cheap and highly tasty energy-dense foods (44).

This study identified that the odds of triple burden of malnutrition were higher in a household with a family size >10. A plausible explanation is that in a household with a large family, providing optimum nutritious food to all the family members and children could be difficult (45, 46). Moreover giving proper care and time to children and the family could be unlikely and this could lead to malnutrition. Likewise, Parity was found a determinant of the triple burden of malnutrition. Higher parity increased the odds of malnutrition. The possible explanation could be that women gain weight during pregnancy, and weight loss does not occur in the post-partum period (47). This mother's obesity/overweight is also correlated with child malnutrition.

The present study revealed that child age and sex were significant factors in malnutrition. Older under-five children were more likely to be malnourished compared to younger ones (48). A previous study (49) revealed that there was an increased frequency of parasite infection in older children leads to a higher prevalence of malnutrition compared to the younger ones. In addition, gender was found a significant determinant of malnutrition where a female child was less likely to be malnourished (50). The cause of the gender gap in malnutrition is unknown however, some studies argued that male children are known to be more vulnerable than females to diseases including lower respiratory infections, diarrhoeal diseases, malaria, and preterm birth. Those problems have been reported as factors for undernutrition among young male children (51, 52). Others also claimed that boys are more vulnerable to environmental problems while playing, such as exposure to toxins and air pollution than girls (53).

Being rural residents was associated with lower odds of the triple burden of malnutrition. This urban-rural difference could be attributable to factors including access to different food types, overcrowding and concurrent disease, physical activity, and sedentary lifestyles. Previous studies depicted that urbanization affects the way of life, and access to processed and junk foods could exacerbate malnutrition among women and children (42, 54).

Our study has some strengths and limitations. It used large nationally representative samples with appropriate statistical modeling. The use of large nationally representative data and multilevel analysis helps to provide more robust estimates of observed associations as well as enhance the generalizability of the results. Despite the strengths, this study used cross-sectional data, which did not indicate a temporal relationship between the factors and triple burden. No important covariates, such as dietary intake, physical activity level, comorbidities, and nutrition status during pregnancy, were incorporated into the study as the DHS did not provide a complete record of these variables.

Conclusions and recommendations

About 1 out of 10 households suffer from the triple burden of malnutrition in low and middle-income countries. This study revealed that several maternal, child, household, and community-level factors have a significant impact on the triple burden of malnutrition among mother-child pairs. Prevention of the problem requires collective efforts from the governments, the scientific and medical communities, and the industry towards changing dietary and lifestyle habits.

Abbreviations

AOR, Adjusted Odds Ratio; DHSs, Demographic and Health Surveys; ICC, Intra cluster correlation coefficient; LMICs, low and middle-income countries; MOR, median odds ratio; PCV,

a proportional change in variance; SDGs, Sustainable Development Goals; WHO, World Health Organization

Declarations

Ethics approval and consent to participate

Permission to access the data was obtained from the measure DHS program (http://www.dhsprogram.com) via online request. The website and the data used were publicly available with no personal identifier. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

Data are available online in a public, open-access repository (www.measuredhs.com/data).

Competing interests

The authors declare that they have no competing interests.

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Author Contributions

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Writing: DC, DGB, MWM, AAK, AZA, MHA, FMA. Review and editing: DC, DGB, MWM, AAK, AZA, MHA, FMA.

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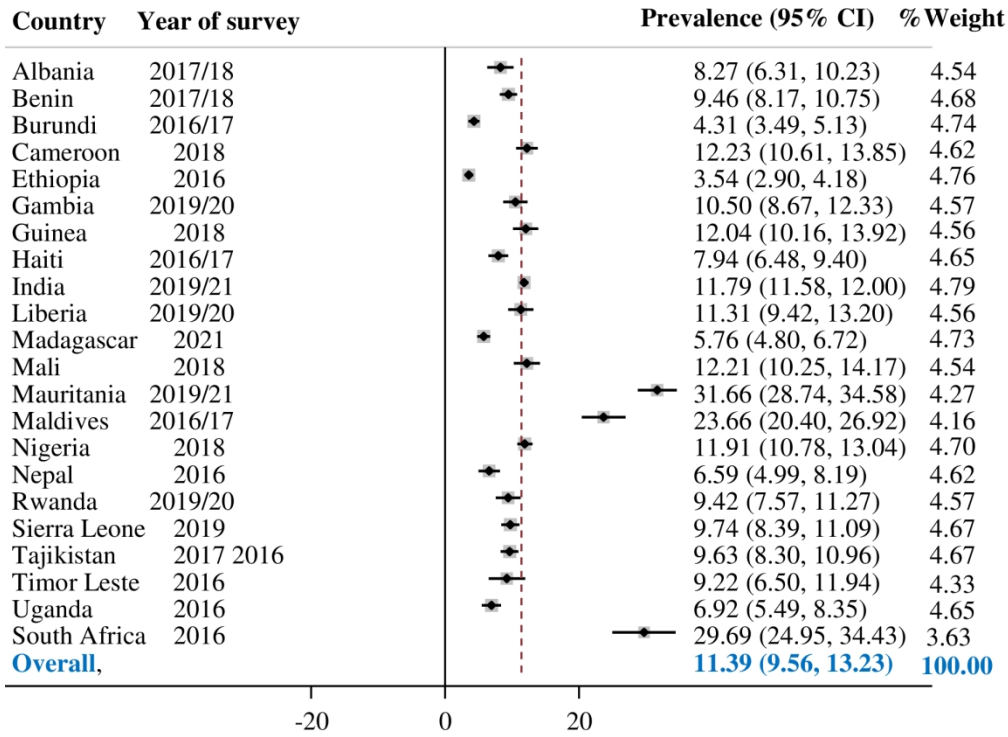
References

1. Meenakshi J. Trends and patterns in the triple burden of malnutrition in India. Agricultural Economics. 2016;47(S1):115-34.
2. Hepatology TLG. Obesity: another ongoing pandemic. 2021. p. 411.
3. Organization WH. Diet, nutrition, and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation: World Health Organization; 2003.
4. Tabarés Seisdedos R. Health effects of overweight and obesity in 195 countries over 25 years. New England Journal of Medicine, 2017, vol 377, num 1, p 13-27. 2017.
5. Dai H, Alsalhe TA, Chalghaf N, Riccò M, Bragazzi NL, Wu J. The global burden of disease attributable to high body mass index in 195 countries and territories, 1990–2017: An analysis of the Global Burden of Disease Study. PLoS medicine. 2020;17(7):e1003198.
6. Ford ND, Patel SA, Narayan KV. Obesity in low-and middle-income countries: burden, drivers, and emerging challenges. Annual review of public health. 2017;38:145-64.
7. Mahumud RA, Sahle BW, Owusu-Addo E, Chen W, Morton RL, Renzaho A. Association of dietary intake, physical activity, and sedentary behaviours with overweight and obesity among 282,213 adolescents in 89 low and middle income to high-income countries. International Journal of Obesity. 2021;45(11):2404-18.
8. Heidkamp RA, Piwoz E, Gillespie S, Keats EC, D'Alimonte MR, Menon P, et al. Mobilising evidence, data, and resources to achieve global maternal and child undernutrition targets and the Sustainable Development Goals: an agenda for action. The Lancet. 2021;397(10282):1400-18.
9. Osendarp S, Akuoku JK, Black RE, Headey D, Ruel M, Scott N, et al. The COVID-19 crisis will exacerbate maternal and child undernutrition and child mortality in low-and middle-income countries. Nature Food. 2021;2(7):476-84.
10. World Health Organisation Fact Sheets—Malnutrition. Available online: https://www.who.int/news-room/fact-sheets/detail/malnutrition (accessed on 26 Nov 2022).
11. Adepoju AA, Allen S. Malnutrition in developing countries: nutrition disorders, a leading cause of ill health in the world today. Paediatrics and Child Health. 2019;29(9):394-400.
12. Sunguya BF, Zhu S, Mpembeni R, Huang J. Trends in prevalence and determinants of stunting in Tanzania: an analysis of Tanzania demographic health surveys (1991–2016). Nutrition Journal. 2019;18(1):1-13.
13. Yang YY, Kaddu G, Ngendahimana D, Barkoukis H, Freedman D, Lubaale YA, et al. Trends and determinants of stunting among under-5s: evidence from the 1995, 2001, 2006 and 2011 Uganda Demographic and Health Surveys. Public health nutrition. 2018;21(16):2915-28.

14. Singh KJ, Chiero V, Kriina M, Alee NT, Chauhan K. Identifying the trend of persistent cluster of stunting, wasting, and underweight among children under five years in northeastern states of India. Clinical Epidemiology and Global Health. 2022;18:101158.
15. Organization. WH. WHO Global Anaemia Estimates, 2021 Edition. Anaemia in Women and Children. Available online: https://www. who. int/data/gho/data/themes/topics/anaemia_in_women_and_children (accessed on 1 December 2022).
16. Koli HB, Nair MG, Shah MC. Impact of structured pre-natal counselling on early initiation of breast feeding and adherence to exclusive breast feeding: a comparative interventional study. International Journal of Reproduction, Contraception, Obstetrics and Gynecology. 2021;10(7):2699-704.
17. Scott N, Delport D, Hainsworth S, Pearson R, Morgan C, Huang S, et al. Ending malnutrition in all its forms requires scaling up proven nutrition interventions and much more: a 129-country analysis. BMC medicine. 2020;18(1):1-19.
18. Mistry SK, Hossain M, Arora A. Maternal nutrition counselling is associated with reduced stunting prevalence and improved feeding practices in early childhood: a post-program comparison study. Nutrition Journal. 2019;18(1):1-9.
19. Norman K, Haß U, Pirlich M. Malnutrition in older adults—recent advances and remaining challenges. Nutrients. 2021;13(8):2764.
20. Forgie AJ, Drall KM, Bourque SL, Field CJ, Kozyrskyj AL, Willing BP. The impact of maternal and early life malnutrition on health: a diet-microbe perspective. BMC medicine. 2020;18(1):1-15.
21. Kirolos A, Goyheneix M, Eliasz MK, Chisala M, Lissauer S, Gladstone M, et al. Neurodevelopmental, cognitive, behavioural and mental health impairments following childhood malnutrition: a systematic review. BMJ global health. 2022;7(7):e009330.
22. Walson JL, Berkley JA. The impact of malnutrition on childhood infections. Current opinion in infectious diseases. 2018;31(3):231.
23. Castro-Rodríguez DC, Rodríguez-González GL, Menjivar M, Zambrano E. Maternal interventions to prevent adverse fetal programming outcomes due to maternal malnutrition: Evidence in animal models. Placenta. 2020;102:49-54.
24. Desyibelew HD, Dadi AF. Burden and determinants of malnutrition among pregnant women in Africa: A systematic review and meta-analysis. PloS one. 2019;14(9):e0221712.
25. Sachs JD, Schmidt-Traub G, Mazzucato M, Messner D, Nakicenovic N, Rockström J. Six transformations to achieve the sustainable development goals. Nature sustainability. 2019;2(9):805-14.
26. Fonseca LM, Domingues JP, Dima AM. Mapping the sustainable development goals relationships. Sustainability. 2020;12(8):3359.
27. Siddiqui F, Salam RA, Lassi ZS, Das JK. The intertwined relationship between malnutrition and poverty. Frontiers in Public Health. 2020;8:453.
28. Rah JH, Melse-Boonstra A, Agustina R, van Zutphen KG, Kraemer K. The Triple Burden of Malnutrition Among Adolescents in Indonesia. SAGE Publications Sage CA: Los Angeles, CA; 2021. p. S4-S8.
29. Luo H, Zyba SJ, Webb P. Measuring malnutrition in all its forms: An update of the net state of nutrition index to track the global burden of malnutrition at country level. Global Food Security. 2020;26:100453.

30. Popkin BM, Corvalan C, Grummer-Strawn LM. Dynamics of the double burden of malnutrition and the changing nutrition reality. The Lancet. 2020;395(10217):65-74.
31. Christian AK, Dake FA. Profiling household double and triple burden of malnutrition in sub-Saharan Africa: Prevalence and influencing household factors. Public Health Nutrition. 2022;25(6):1563-76.
32. Wong C, Zalilah M, Chua E, Norhasmah S, Chin Y, Siti Nur'Asyura A. Double-burden of malnutrition among the indigenous peoples (Orang Asli) of Peninsular Malaysia. BMC Public Health. 2015;15(1):1-9.
33. Sunuwar DR, Singh DR, Pradhan PMS. Prevalence and factors associated with double and triple burden of malnutrition among mothers and children in Nepal: evidence from 2016 Nepal demographic and health survey. BMC Public Health. 2020;20(1):1-11.
34. Villena-Esponera MP, Moreno-Rojas R, Molina-Recio G. Food insecurity and the double burden of malnutrition of indigenous refugee Épera Siapidara. Journal of immigrant and minority health. 2019;21(5):1035-42.
35. Tiwari N. The Influence of Single Parent Environment on Children's Learning and Development.
36. Molitoris J. Breastfeeding during pregnancy and its association with childhood malnutrition and pregnancy loss in low-and middle-income countries. Lund Papers in Economic Demography. 2018;2018(3):1-81.
37. Raihana S, Alam A, Huda TM, Dibley MJ. Factors associated with delayed initiation of breastfeeding in health facilities: secondary analysis of Bangladesh demographic and health survey 2014. International Breastfeeding Journal. 2021;16(1):1-13.
38. Belachew A. Timely initiation of breastfeeding and associated factors among mothers of infants age 0–6 months old in Bahir Dar City, Northwest, Ethiopia, 2017: a community based cross-sectional study. International breastfeeding journal. 2019;14(1):1-6.
39. Saaka M, Hammond AY. Caesarean section delivery and risk of poor childhood growth. Journal of nutrition and metabolism. 2020;2020.
40. Pekmez CT, Dragsted LO, Brahe LK. Gut microbiota alterations and dietary modulation in childhood malnutrition–the role of short chain fatty acids. Clinical Nutrition. 2019;38(2):615-30.
41. Kibria A, Muhammed G, Swasey K, Hasan MZ, Sharmeen A, Day B. Prevalence and factors associated with underweight, overweight and obesity among women of reproductive age in India. Global health research and policy. 2019;4(1):1-12.
42. Kumar P, Chauhan S, Patel R, Srivastava S, Bansod DW. Prevalence and factors associated with triple burden of malnutrition among mother-child pairs in India: a study based on National Family Health Survey 2015–16. BMC Public Health. 2021;21(1):1-12.
43. Sekiyama M, Jiang HW, Gunawan B, Dewanti L, Honda R, Shimizu-Furusawa H, et al. Double burden of malnutrition in rural West Java: household-level analysis for father-child and mother-child pairs and the association with dietary intake. Nutrients. 2015;7(10):8376-91.
44. Liguori J, Trübswasser U, Pradeilles R, Le Port A, Landais E, Talsma EF, et al. How do food safety concerns affect consumer behaviors and diets in low-and middle-income countries? A systematic review. Global Food Security. 2022;32:100606.
45. Drammeh W, Hamid NA, Rohana A. Determinants of household food insecurity and its association with child malnutrition in Sub-Saharan Africa: A review of the literature. Current Research in Nutrition and Food Science Journal. 2019;7(3):610-23.

46. Serbesa ML, Iffa MT, Geleto M. Factors associated with malnutrition among pregnant women and lactating mothers in Miesso Health Center, Ethiopia. European Journal of Midwifery. 2019;3.
47. Bhavadharini B, Anjana RM, Deepa M, Jayashree G, Nrutya S, Shobana M, et al. Gestational weight gain and pregnancy outcomes in relation to body mass index in Asian Indian women. Indian Journal of Endocrinology and Metabolism. 2017;21(4):588.
48. Sinha RK, Dua R, Bijalwan V, Rohatgi S, Kumar P. Determinants of stunting, wasting, and underweight in five high-burden pockets of four Indian states. Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine. 2018;43(4):279.
49. Pal A, Manna S, Dalui R, Mukhopadhyay R, Dhara PC. Undernutrition and associated factors among children aged 5–10 years in West Bengal, India: a community-based cross-sectional study. Egyptian Pediatric Association Gazette. 2021;69(1):1-12.
50. Anuradha R, Sivanandham R, Salome SD, Francis R, Roopa D, Sampavi S, et al. Nutritional status of children aged 3-6 years in a rural area of Tamilnadu. Journal of clinical and diagnostic research: JCDR. 2014;8(10):JC01.
51. Hawkes S, Buse K. Gender and global health: evidence, policy, and inconvenient truths. The Lancet. 2013;381(9879):1783-7.
52. Thurstans S, Opondo C, Seal A, Wells J, Khara T, Dolan C, et al. Boys are more likely to be undernourished than girls: a systematic review and meta-analysis of sex differences in undernutrition. BMJ global health. 2020;5(12):e004030.
53. Asfaw M, Wondaferash M, Taha M, Dube L. Prevalence of undernutrition and associated factors among children aged between six to fifty nine months in Bule Hora district, South Ethiopia. BMC Public health. 2015;15(1):1-9.
54. Nagarkar AM, Kulkarni SS. Obesity and its effects on health in middle-aged women from slums of Pune. Journal of Mid-life Health. 2018;9(2):79.



NOTE: Weights are from random-effects model

161x123mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2, 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7,8
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8,9
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	*9*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10/12
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	12/15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Triple burden of malnutrition among mother-child pairs in low and middle-income countries: A cross-sectional study

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Triple burden of malnutrition among mother-child pairs in low and middle-income countries: A cross-sectional study

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Abstract

Objective: This study aimed to assess the prevalence and determinants of the triple burden of malnutrition among mother-child pairs in low-and middle-income countries.

Design: Cross-Sectional Study

Setting: Low-and middle-income countries

Participants: Women and children

Primary outcome: Triple burden of malnutrition (overweight/obese mother with undernourished and anemic under 5 years child)

Methods: Data for this study were drawn from recent 22 low and middle-income countries Demographic and Health Surveys (DHSs). A total weighted sample of 116,795 mother-child pairs was included in the study. STATA version 14.2 was used to clean, code and analyze the data. Multilevel logistic regression was employed to identify factors associated with the problem. Adjusted odds ratio with 95% CI and a P value <0.05 was reported to indicate statistical association. Model fitness and comparison were done using ICC, MOR, PCV, and deviance.

Result: The pooled prevalence of the triple burden of malnutrition among mother-child pairs was 11.39%. It showed statistically significant positive associations with mothers aged ≥35 years (AOR=2.25,95%CI 2.08-2.44), family size >10 (AOR=1.17,95%CI 1.08-1.26), delivery by CS (AOR=1.93,95%CI 1.83-2.03), the richest household (AOR=1.72,95%CI 1.56-1.88), grand multiparous (AOR=1.62, 95% CI 1.46-1.81), age of child 36-47 months (AOR=1.77, 95% CI 1.64-1.90), at a p-value of <0.05. Whereas breastfeeding (AOR=0.94,95%CI 0.89-0.99), married mothers (AOR=0.87,95%CI 0.78-0.96), female children (AOR=0.88,95%CI 0.84-0.92), improved toilet (AOR=0.23,95%CI 0.17-0.29), improved source of drinking water (AOR=0.28,95%CI 0.21-

0.35), rural residents (AOR=0.66,95%CI 0.62-0.69) had a contrasting relationship with the triple burden of malnutrition

Conclusion: About 1 out of 10 households suffer from the triple burden of malnutrition in low and middle-income countries. This study revealed that several maternal, child, household, and community-level factors have a significant impact on the triple burden of malnutrition among mother-child pairs.

Keywords: Triple burden, mother-child pairs, malnutrition, low and middle-income countries.

Strengths and limitations of this study

- The findings were supported by large datasets covering 22 LMICs.
- We employed multilevel analysis which is an appropriate methodology for such data
- The data were collected using a common internationally acceptable methodological procedure.
- DHS used a cross-sectional survey design, and the causal relationship between the triple burden of malnutrition and the independent variables cannot be established.
- We didn't include important covariates such as dietary intake, physical activity level, or comorbidities as the DHS did not collect information on these variables

Background

The triple burden of malnutrition, defined as the coexistence of overnutrition, undernutrition, and micronutrient deficiencies is increasing in low and middle-income countries (LMICs) (1). The World Health Organization (WHO) characterized overnutrition (Obesity and overweight) as a pandemia of a major public health concern due to the increased frequency of the problem in many countries (2). It is ranked as the sixth leading cause of disability-adjusted life years (DALYs) and accounts for approximately 4 million people dying each year worldwide (3-5). Several previous studies have shown, following marked dietary change that obesity/overweight is increasing more rapidly in low and middle-income countries compared to higher-income countries (6, 7).

Similarly, undernutrition continues to be a major public health concern throughout the developing world (8, 9). Nearly half of all deaths in children under 5 are attributable to undernutrition and it encompasses wasting, stunting, underweight, and micronutrient deficiencies (anemia) (10, 11). Despite stunting having declined steadily, faster progress is needed to reach the 2030 target (12, 13). Wasting and underweight persisting at alarming rates require a reversal in trajectory if the 2030 target is to be achieved (14). Since 2000, a significant reduction in the prevalence of anemia in children under five has been observed in many low- and lower-middle-income countries (15). Children are more vulnerable to inadequate pre-natal, infant, and young child nutrition, particularly in resource-constrained settings (16, 17). Endorsing early childhood feeding best practices is crucial to improve the health of children (18).

Malnutrition has a tremendous negative impact on the normal functioning of every organ system (19). It can cause permanent, widespread damage to a child's growth, development, and well-being (20). Scientific evidence has shown that malnutrition in children is associated with poorer school performance, increased susceptibility to infections, and slow recovery from illness (21, 22).

Maternal malnutrition increases the risk of poor pregnancy outcomes including obstructed labor, premature or low-birth-weight babies, and postpartum hemorrhage (23, 24). To reduce the problem the United Nations (UN) adopted the Sustainable Development Goals (SDGs), especially those targeted to end poverty in all its forms everywhere (SDG 1), end hunger, achieve food security, improve nutrition, promote sustainable agriculture (SDG 2), ensure healthy lives, and promote well-being for all at all ages (SDG 3) (25, 26).

Previous literature recognizes the basic and underlying causes of malnutrition including the environmental, economic, and sociopolitical contextual factors, with poverty having a central role (11, 27-29). The triple burden of malnutrition among mother-child pairs is a relatively new issue and only a few country-based studies explore the problem which couldn't give a panoramic view of the problem in LMICs (30-32). Given the persistent and high levels of the problem in these countries, there is a strong need for action. To design and deliver effective interventions adequate understanding of the socioeconomic, environmental, and cultural factors is highly important. Besides if the SDG targets are to be met, coordinated action is required toward not only sustaining current rates of decline but also accelerating progress. Therefore, the objective of this study was to assess the prevalence of the triple burden of malnutrition among mothers and children and the potential factors associated with it in low and middle-income countries.

Materials and methods

Study design, setting, and period

The present study is based on 22 low and middle-income countries that have had Demographic and Health Surveys (DHS) from 2016-2020. The DHS used a cross-sectional survey study design to collect data and provide population and health indicators at the national level. The list of those countries and the respective year of surveys is provided in Table 1.

Table 1. Study setting and year of surveys

Country	Year of survey	Region
Albania	2017/18	Southeastern Europe
Benin	2017/18	West Africa
Burundi	2016/17	East-central Africa
Cameroon	2018	West-central Africa
Ethiopia	2016	East Africa
Gambia	2019/20	West Africa
Guinea	2018	West Africa
Haiti	2016/17	Caribbean
India	2019/21	South Asia
Liberia	2019/20	West Africa
Madagascar	2021	East Africa
Mali	2018	West Africa
Mauritania	2019/21	Northwest Africa
Maldives	2016/17	South Asia
Nigeria	2018	West Africa
Nepal	2016	South Asia
Rwanda	2019/20	East Africa
Sierra Leone	2019	West Africa
Tajikistan	2017	Central Asia
Timor Leste	2016	South Asia
Uganda	2016	East Africa
South Africa	2016	South Africa

Data source and sampling procedure

The current analyses was based on pooled data from DHSs in 22 LMICs. These are nationally representative surveys that collect data on reproductive, maternal, neonatal, child health, and nutrition in LMIC. The surveys are similarly designed that used standardized questionnaires and data collection procedures, allowing therefore comparability of results. The survey employed a two-stage cluster sampling technique. In the first stage, the selection of proportional clusters/enumeration areas was performed using each country's most recent population and housing census as a sampling frame. In the second stage, a systematic selection of households from the newly created cluster was performed. A detailed description of the DHS sampling design and data collection procedures has been found in each country's DHS report. The study population for

this study was mother-child pairs. Weighting was done using the complex sample design weighting and the "svyset" Stata command was applied. Variables v005 (sampling weight), v021 (primary sampling unit), and v023 (stratification used in sample design) were used, and as the result, a total weighted sample of 116,795 mother-child pairs was included in the analysis.

Definition of variables

Outcome variable:

The triple burden of malnutrition was the outcome variable of this study where the mother was overweight/obese and children under 5 years of age were undernourished and anemic (31, 33). At the same household level, first, we created four different categories of malnutrition such as overweight/obese mother and stunted child, overweight/obese mother and wasted child, overweight/obese mother and underweight child, and overweight/obese mother and anemic child. Then we further combined overweight/obese mothers, undernourished children, and anemic children to generate the triple burden of malnutrition. Categorization was made based on height-for-age z-score (HAZ), standard deviations (SD), weight-for-height z-score (WHZ), weight-for-age z-score (WAZ), hemoglobin level, and body mass index (BMI).

Stunting dichotomized and coded into 0=Not stunted (HAZ -2SD and above) & 1= Stunted (HAZ < -2SD);

Wasting dichotomized and coded into 0=Not wasted (WHZ-2SD to +2SD) and 1=Wasted (WHZ < -2SD);

Underweight dichotomized and coded into 0= Not underweight (WHZ-2SD and above) & 1= Underweight (WAZ < -2SD);

Child anemia dichotomized and coded into 0= Not anemic (hemoglobin level > 11 g/dl), & 1= Anemic (hemoglobin level < 11 g/dl);

Mother's BMI dichotomized and coded into 0= Normal (18.5–24.9 kg/m2) & 1= Overweight/Obese (≥25 kg/m2)

The triple burden of malnutrition was dichotomized and coded into 0= NO (not overweight/obese mother and not undernourished child plus not anemic child, and 1= YES (overweight/obese mother and undernourished child plus anemic child)

An undernourished child is a child who is stunted or wasted or underweight.

Independent variables:

Based on previous works of literature and the likelihood of influencing the outcome of interest, several explanatory variables including the age of mothers, mother's education, marital status, current breastfeeding, delivery by cesarean section, family size, wealth index, media access, parity, age of the child, sex of the child, type of toilet facility, source of drinking water, residence and distance to health facility were considered.

Statistical analyses

We append the dataset of each country to generate pooled data. The data extraction, coding, and analysis were carried out using STATA software version 14.2. We weighted the sample to restore the representativeness of the sample so that the total sample looks like the country's actual population. Due to the hierarchical nature of the DHS, the multilevel analysis was fitted to identify significantly associated factors. Four models were fitted; the null model (with no predictors), the model I (adjusted for individual-level variables only), model II (adjusted for community-level variables only), and model III (model adjustment for both individual and community-level variables simultaneously). Adjusted OR (AOR) with 95% CI and $p<0.05$ were used to determine significant predictors. Model fitness and comparison were done using Intraclass Correlation

Coefficient (ICC), Proportional Change in Variance (PCV), Median Odds Ratio (MOR), the Likelihood Ratio test (LR), and deviance computed.

Patient and public involvement statement

As our study used secondary analysis of DHS data, participants and the public were not involved in the study design or planning of the study. The study participants were not consulted to interpret the results and write or editing of this document for readability or accuracy.

Results

Demographics and socioeconomic characteristics

A total of 116,795 mother-child pairs were included in the study. Over half (56.48%) of mothers were in the age category of 25-34 years. About 22.98% of mothers were illiterate and the majority (46.39%) had attended secondary education. Approximately 95.73% of mothers were married and 62.89% were currently breastfeeding. About 20.33% and 21.21% of the households were in the low wealth quintile of poorest and poorer respectively. Over a quarter (27.62%) of the families had never been exposed to any type of media. The majority of the children (32.59%) were aged ≤12 months. A large proportion (83.60%) of the households had improved sources of drinking water and almost two-thirds (67.02%) of the households had improved toilet facilities. Almost three fourth (71.03%) of participants lived in rural areas and for over a quarter (27.42%) of those participants, the distance to access health facilities was a big problem (**Table 2**).

Table 2. Socio-demographic characteristics of the study participants

Variables	Categories	Unweighted frequency (%)	Weighted frequency (%)
Age of mothers	15-24	34,983 (29.05)	35,918 (30.75)
	25-34	68,386 (56.78)	65,971 (56.48)

	≥35	17,073 (14.18)	14,906 (12.76)
Mothers education	No education	27,995 (23.24)	26,845 (22.98)
	Primary education	19,684 (16.34)	18,633 (15.95)
	Secondary	57,008 (47.33)	54,185 (46.39)
	Higher	15,755 (13.08)	17,131 (14.67)
Mothers marital status	Not in union	5,583 (4.64)	4,987 (4.27)
	Married	114,859 (95.36)	111,807 (95.73)
Currently breastfeeding	No	44,160 (36.66)	43,338 (37.11)
	Yes	76,282 (63.34)	73,457 (62.89)
Delivery by cesarean section	No	99,291 (82.49)	93,974 (80.51)
	Yes	21,077 (17.51)	22,748 (19.49)
Family size	≤5	56,365 (46.80)	53,677 (45.96)
	6-10	54,605 (45.34)	53,258 (45.60)
	>10	9,472 (7.86)	9,859 (8.44)
Wealth index	Poorest	28,097 (23.33)	23,749 (20.33)
	Poorer	27,352 (22.71)	24,774 (21.21)
	Middle	24,741 (20.54)	24,330 (20.83)
	Richer	22,180 (18.42)	23,880 (20.45)
	Richest	18,072 (15.00)	20,061 (17.18)
Media access	No	33,942 (28.18)	32,256 (27.62)
	Yes	86,500 (71.82)	84,539 (72.38)
Parity	Primiparous	36,241 (30.09)	35,333 (30.25)
	Multiparous	76,092 (63.18)	73,823 (63.21)
	Grand Multiparous	8,109 (6.73)	7,639 (6.54)
Age of child	≤12	38,959 (32.35)	38,059 (32.59)
	13-23	25,382 (21.07)	24,819 (21.25)
	24-35	22,208 (18.44)	21,478 (18.39)
	36-47	17,948 (14.90)	17,204 (14.73)
	48-59	15,945 (13.24)	15,234 (13.04)
Sex of child	Male	63,660 (52.86)	62,008 (53.09)
	Female	56,782 (47.14)	54,787 (46.91)
Type of toilet facility	Unimproved	37,519 (31.15)	38,518 (32.98)
	Improved	82,923 (68.85)	78,277 (67.02)
Source of drinking water	Unimproved	20,959 (17.40)	19,159 (16.40)
	Improved	99,483 (82.60)	97,636 (83.60)
Residence	Urban	28,722 (23.85)	33,838 (28.97)
	Rural	91,720 (76.15)	82,957 (71.03)
Distance to health facility	No problem	84,605 (70.25)	84,776 (72.58)
	Big problem	35,837 (29.75)	32,019 (27.42)

Prevalence of triple burden of malnutrition

In 22 low and middle-income countries, the pooled prevalence of the triple burden of malnutrition among mother-child pairs was found at 11.39 % (95% CI 9.56%, 13.23%). Ethiopia has the lowest (3.54 %) prevalence of triple burden while Mauritania (31.66%) bears the highest (**Figure 1**).

Fig 1. The pooled prevalence of the triple burden of malnutrition

Multilevel analyses

Random parameter estimation and model selection

Based on the result of random effect analysis, the ICC of the null model was 0.30, indicating that 30% of the total variability in triple burden prevalence was attributable to between-cluster variability, while about 70% was due to individual differences. The null model MOR was 3.04, which indicates that a mother/child from a cluster with a high triple burden prevalence has a 3.04 times higher probability of being malnourished than a mother/child from a cluster with a lower prevalence. Model III was the best-fitted model since it has the highest log likelihood (-91665) and the lowest deviance (183,330) value **(Table 3)**.

Factors associated with the triple burden of malnutrition (Fixed effects)

The triple burden of malnutrition was statistically significant with mothers aged 25-34 years (AOR=1.54, 95% CI 1.45 - 1.63), ≥35 years (AOR=2.25, 95% CI 2.08 - 2.44), mothers attended secondary education (AOR=1.08, 95% CI 1.02-1.15), family size >10 (AOR=1.17, 95% CI 1.08 - 1.26), delivery by CS (AOR=1.93, 95% CI 1.83 - 2.03), the richer household (AOR=1.63, 95% CI 1.49 - 1.76), the richest household (AOR=1.72, 95% CI 1.56 - 1.88), multiparous (AOR=1.42, 95% CI 1.34 - 1.49), grand multiparous (AOR=1.62, 95% CI 1.46 - 1.81), age of child 36-47 months (AOR=1.77, 95% CI 1.64 - 1.90), age of child 48-59 (AOR=1.51, 95% CI 1.39 - 1.64), breastfeeding (AOR=0.94, 95% CI 0.89 - 0.99), married mothers (AOR=0.87, 95% CI 0.78 - 0.96),

female children (AOR=0.88, 95% CI 0.84 - 0.92), improved toilet facility (AOR=0.23, 95% CI 0.17 - 0.29), improved source of drinking water (AOR=0.28, 95% CI 0.21 - 0.35), rural residents (AOR=0.66, 95% CI 0.62 - 0.69) at a p-value of <0·05 **(Table 3)**.

Table 3. Multivariable multilevel logistic regression analysis of the triple burden of malnutrition.

Variables	Categories	Null model	Model I AOR 95% CI	Model II AOR 95% CI	Model III AOR 95% CI
Age of mothers	15-24		1.00		1.00
	25-34		1.54 (1.46 - 1.63)**	—	1.54 (1.45 - 1.63)**
	≥35		2.28 (2.11 - 2.47)**	—	2.25 (2.08 - 2.44)**
Mothers education	No education		1.00		1.00
	Primary education		1.04 (0.97 - 1.12)	—	1.04 (0.97 - 1.12)
	Secondary		1.08 (1.01 - 1.15)*	—	1.08 (1.02 - 1.15)*
	Higher		0.94 (0.86 - 1.02)	—	0.94 (0.86 - 1.02)
Mothers marital status	Not in union		1.00		1.00
	Married		0.83 (0.75 - 0.93)*	—	0.87 (0.78 - 0.96)**
Currently breast feeding	No		1.00		1.00
	Yes		0.92 (0.87 - 0.97)*	—	0.94 (0.89 - 0.99)*
Delivery by CS	No		1.00		1.00
	Yes		1.94 (1.84 - 2.04)**	—	1.93 (1.83 - 2.03)**
Family size	≤5		1.00		1.00
	6-10		1.00 (0.97 - 1.08)	—	1.01 (0.98 - 1.08)
	>10		1.14 (1.06 - 1.24)**	—	1.17 (1.08 - 1.26)**
Wealth index	Poorest		1.00		1.00
	Poorer		1.41 (1.31 - 1.52)**	—	1.38 (1.28 - 1.49)**
	Middle		1.60 (1.48 - 1.73)**	—	1.49 (1.38 - 1.62)**
	Richer		1.86 (1.72 - 2.02)**	—	1.63 (1.49 - 1.76)**
	Richest		2.15 (1.97 - 2.35)**	—	1.72 (1.56 - 1.88)**
Media access	No		1.00		1.00
	Yes		1.01 (0.98 - 1.08)	—	1.02 (0.99 - 1.11)
Parity	Primiparous		1.00		1.00
	Multiparous		1.42 (1.34 - 1.50)**	—	1.42 (1.34 - 1.49)**
	Grand Multiparous		1.61 (1.44 - 1.79)**	—	1.62 (1.46 - 1.81)**
Age of child	≤12		1.00		1.00
	13-23		1.41 (1.32 - 1.50)**	—	1.41 (1.32 - 1.50)**
	24-35		1.62 (1.52 - 1.73)**	—	1.63 (1.53 - 1.74)**
	36-47		1.75 (1.62 - 1.89)**	—	1.77 (1.64 - 1.90)**
	48-59		1.50 (1.38 - 1.62)**	—	1.51 (1.39 - 1.64)**
Sex of child	Male		1.00		1.00
	Female		0.88 (0.84 - 0.92)**	—	0.88 (0.84 - 0.92)**

Type of toilet facility	Unimproved		1.00		1.00
	Improved		0.24 (0.18 - 1.31)	—	0.23 (0.17 - 0.29)**
Source of drinking water	Unimproved		1.00		1.00
	Improved		0.21 (0.16 - 0.28)	—	0.28 (0.21 - 0.35)**
Community-level variables					
Residence	Urban			1.00	1.00
	Rural		—	0.49 (0.46 - 0.52)**	0.66 (0.62 - 0.69)**
Distance to health facility	No problem			1.00	1.00
	Big problem		—	0.87 (0.82 - 0.91)**	0.94 (0.89 - 0.98)**
Random effect					
	Variance	1.40	1.24	1.31	1.23
	ICC	0.30	0.27	0.28	0.27
	MOR	3.04	2.88	2.96	2.85
	PCV	Reff	11.42	6.43	12.14
Model comparison					
	Log likelihood ratio	-100585	-92108	-97815	-91665
	Deviance	201,170	184,216	195,630	183,330

* = P-value < 0.05, ** = P-value < 0.01,
ICC = Inter cluster correlation coefficient, MOR =Median odds ratio, PCV = proportional change in variance. AOR=adjusted odds ratio; CI= confidence interval,

Discussion

LMICs are increasingly facing the triple burden of malnutrition where women and children are among the hardest hit by the burden (34, 35). This study assessed the triple burden of malnutrition (co-occurrence of undernutrition, overweight/obesity, and anemia among mother-child pairs) in the same household using nationally representative data. The finding showed that the prevalence of triple burden found at 11.39 % (95% CI 9.56%, 13.23%), Ethiopia has the lowest (3.54 %) prevalence while Mauritania (31.66%) bears the highest. The variation among countries could be attributed to differences in socio-economic status, food environment, physical activity, genetic factors, health care system strength, national policy, and political commitments.

The study revealed that several maternal, child, household, and community-level factors have a significant impact on the triple burden of malnutrition among mother-child pairs. It has found a parallel correlation between the triple burden of malnutrition and maternal age. The odds of being

malnourished increase as the age of the mother increases. This is in agreement with previous studies where older mothers bear the highest risk compared to younger ones (31, 36). The possible explanation could be because of reduced physical activity, less energy requirement, and hormonal changes among older mothers. Similarly, mothers who have attended secondary education were more likely to be malnourished (31). A plausible explanation for this could be the shifts from manual labor to more sedentary occupations and the related decline in physical activity.

Being married reduced the risk of the triple burden of malnutrition. Partners together could generate more money, reduce food insecurity, and tend to take better care of themselves and their children. It is been reported that children in single-parent households suffered from undernutrition significantly more than children brought up by both parents (37, 38). Likewise, this study revealed breastfeeding reduced the triple burden of malnutrition. Breastfeeding plays a vital role in the prevention of different forms of childhood malnutrition (39). Delivery by cesarean section (C-section) delays the timely initiation of breastfeeding and pre-lacteal feeding (40). Previous studies have reported that C-section increases maternal obesity and negatively affect the breastfeeding of children, which results suffer from malnutrition (41, 42). Moreover, malnutrition in children is related to gut microbiota alteration and C-section contributes to microbial alterations in the small intestine (43).

Our study revealed a parallel relationship between the household wealth quintiles and the triple burden of malnutrition. As household income increases, the odds of malnutrition increase (30, 44). High income could increase the purchasing power for food, influencing the type of foods consumed and the intake of prepared or processed food (34). Economic growth and the food industry's rapid penetration into the market have resulted in diets based on energy-dense and nutrient-poor foods (45). In recent years, the dietary preference in LMICs has changed as the food

environment is dominated by media advertising and relatively cheap and highly tasty energy-dense foods (46).

The odds of the triple burden of malnutrition were higher in a household with a family size >10. A plausible explanation is that in a household with a large family, providing optimum nutritious food to all the family members and children could be difficult (47, 48). Moreover giving proper care and time to children and the family could be unlikely and this could lead to malnutrition. Likewise, Parity was found a determinant of the triple burden of malnutrition. Higher parity increased the odds of malnutrition. The possible explanation could be that women gain weight during pregnancy, and weight loss does not occur in the post-partum period (49). This mother's obesity/overweight is also correlated with child malnutrition.

The present study revealed that child age and sex were significant factors for malnutrition. Older under-five children were more likely to be malnourished compared to younger ones (50). A previous study (51) revealed that there was an increased frequency of parasite infection in older children leads to a higher prevalence of malnutrition compared to the younger ones. In addition, gender was found a significant determinant of malnutrition where a female child was less likely to be malnourished (52). The cause of the gender gap in malnutrition is unknown however, some studies argued that male children are known to be more vulnerable than females to diseases including lower respiratory infections, diarrhoeal diseases, malaria, and preterm birth. Those problems have been reported as factors for undernutrition among young male children (53, 54). Others also claimed that boys are more vulnerable to environmental problems while playing, such as exposure to toxins and air pollution than girls (55).

Being rural residents was associated with lower odds of the triple burden of malnutrition. This urban-rural difference could be attributable to factors including access to different food types,

overcrowding and concurrent disease, physical activity, and sedentary lifestyles. Previous studies depicted that urbanization affects the way of life, and access to processed and junk foods could exacerbate malnutrition among women and children (30, 56).

Our study has some strengths and limitations. It used large nationally representative samples with appropriate statistical modeling. The use of large nationally representative data and multilevel analysis helps to provide more robust estimates of observed associations as well as enhance the generalizability of the results. Despite the strengths, this study used cross-sectional data, which did not indicate a temporal relationship between the factors and triple burden. No important covariates, such as dietary intake, physical activity level, comorbidities, and nutrition status during pregnancy, were incorporated into the study as the DHS did not provide a complete record of these variables.

Conclusions and recommendations

About 1 out of 10 households suffer from the triple burden of malnutrition in low and middle-income countries. This study revealed that several maternal, child, household, and community-level factors have a significant impact on the triple burden of malnutrition among mother-child pairs. The triple burden requires the governments, the scientific and medical communities, and the industry's efforts in changing dietary and lifestyle habits to address all forms of malnutrition and should focus on women's nutrition to break the intergenerational triple burden of malnutrition.

Abbreviations

AOR, Adjusted Odds Ratio; DHSs, Demographic and Health Surveys; ICC, Intra cluster correlation coefficient; LMICs, low and middle-income countries; MOR, median odds ratio; PCV, a proportional change in variance; SDGs, Sustainable Development Goals; WHO, World Health Organization

Declarations

Ethics approval and consent to participate

Permission to access the data was obtained from the measure DHS program (http://www.dhsprogram.com) via online request. The website and the data used were publicly available with no personal identifier. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

Data are available online in a public, open-access repository (www.measuredhs.com/data).

Competing interests

The authors declare that they have no competing interests.

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Author Contributions

Conceptualization: DC. Study design: DC, DGB, MWM, AAK, AZA, MHA, NWT and FMA. Execution: DC, DGB, MWM, AAK, AZA, MHA, NWT and FMA. Acquisition of the data: DC, DGB, MWM, AAK, AZA, MHA, NWT and FMA. Analysis and interpretation: DC, DGB, MWM, AAK, AZA, MHA, NWT and FMA. Writing: DC, DGB, MWM, AAK, AZA, MHA, NWT and FMA. Review and editing: DC, DGB, MWM, AAK, AZA, MHA, NWT and FMA.

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References

1. Meenakshi J. Trends and patterns in the triple burden of malnutrition in India. Agricultural Economics. 2016;47(S1):115-34.
2. Hepatology TLG. Obesity: another ongoing pandemic. 2021. p. 411.
3. Organization WH. Diet, nutrition, and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation: World Health Organization; 2003.
4. Tabarés Seisdedos R. Health effects of overweight and obesity in 195 countries over 25 years. New England Journal of Medicine, 2017, vol 377, num 1, p 13-27. 2017.
5. Dai H, Alsalhe TA, Chalghaf N, Riccò M, Bragazzi NL, Wu J. The global burden of disease attributable to high body mass index in 195 countries and territories, 1990–2017: An analysis of the Global Burden of Disease Study. PLoS medicine. 2020;17(7):e1003198.
6. Ford ND, Patel SA, Narayan KV. Obesity in low-and middle-income countries: burden, drivers, and emerging challenges. Annual review of public health. 2017;38:145-64.
7. Mahumud RA, Sahle BW, Owusu-Addo E, Chen W, Morton RL, Renzaho A. Association of dietary intake, physical activity, and sedentary behaviours with overweight and obesity among 282,213 adolescents in 89 low and middle income to high-income countries. International Journal of Obesity. 2021;45(11):2404-18.
8. Heidkamp RA, Piwoz E, Gillespie S, Keats EC, D'Alimonte MR, Menon P, et al. Mobilising evidence, data, and resources to achieve global maternal and child undernutrition targets and the Sustainable Development Goals: an agenda for action. The Lancet. 2021;397(10282):1400-18.
9. Osendarp S, Akuoku JK, Black RE, Headey D, Ruel M, Scott N, et al. The COVID-19 crisis will exacerbate maternal and child undernutrition and child mortality in low-and middle-income countries. Nature Food. 2021;2(7):476-84.
10. World Health Organisation Fact Sheets—Malnutrition. Available online: https://www.who.int/news-room/fact-sheets/detail/malnutrition (accessed on 26 Nov 2022).
11. Adepoju AA, Allen S. Malnutrition in developing countries: nutrition disorders, a leading cause of ill health in the world today. Paediatrics and Child Health. 2019;29(9):394-400.
12. Sunguya BF, Zhu S, Mpembeni R, Huang J. Trends in prevalence and determinants of stunting in Tanzania: an analysis of Tanzania demographic health surveys (1991–2016). Nutrition Journal. 2019;18(1):1-13.
13. Yang YY, Kaddu G, Ngendahimana D, Barkoukis H, Freedman D, Lubaale YA, et al. Trends and determinants of stunting among under-5s: evidence from the 1995, 2001, 2006 and 2011 Uganda Demographic and Health Surveys. Public health nutrition. 2018;21(16):2915-28.
14. Singh KJ, Chiero V, Kriina M, Alee NT, Chauhan K. Identifying the trend of persistent cluster of stunting, wasting, and underweight among children under five years in northeastern states of India. Clinical Epidemiology and Global Health. 2022;18:101158.
15. Organization. WH. WHO Global Anaemia Estimates, 2021 Edition. Anaemia in Women and Children. Available online: https://www. who. int/data/gho/data/themes/topics/anaemia_in_women_and_children (accessed on 1 December 2022).

16. Koli HB, Nair MG, Shah MC. Impact of structured pre-natal counselling on early initiation of breast feeding and adherence to exclusive breast feeding: a comparative interventional study. International Journal of Reproduction, Contraception, Obstetrics and Gynecology. 2021;10(7):2699-704.
17. Scott N, Delport D, Hainsworth S, Pearson R, Morgan C, Huang S, et al. Ending malnutrition in all its forms requires scaling up proven nutrition interventions and much more: a 129-country analysis. BMC medicine. 2020;18(1):1-19.
18. Mistry SK, Hossain M, Arora A. Maternal nutrition counselling is associated with reduced stunting prevalence and improved feeding practices in early childhood: a post-program comparison study. Nutrition Journal. 2019;18(1):1-9.
19. Norman K, Haß U, Pirlich M. Malnutrition in older adults—recent advances and remaining challenges. Nutrients. 2021;13(8):2764.
20. Forgie AJ, Drall KM, Bourque SL, Field CJ, Kozyrskyj AL, Willing BP. The impact of maternal and early life malnutrition on health: a diet-microbe perspective. BMC medicine. 2020;18(1):1-15.
21. Kirolos A, Goyheneix M, Eliasz MK, Chisala M, Lissauer S, Gladstone M, et al. Neurodevelopmental, cognitive, behavioural and mental health impairments following childhood malnutrition: a systematic review. BMJ global health. 2022;7(7):e009330.
22. Walson JL, Berkley JA. The impact of malnutrition on childhood infections. Current opinion in infectious diseases. 2018;31(3):231.
23. Castro-Rodríguez DC, Rodríguez-González GL, Menjivar M, Zambrano E. Maternal interventions to prevent adverse fetal programming outcomes due to maternal malnutrition: Evidence in animal models. Placenta. 2020;102:49-54.
24. Desyibelew HD, Dadi AF. Burden and determinants of malnutrition among pregnant women in Africa: A systematic review and meta-analysis. PloS one. 2019;14(9):e0221712.
25. Sachs JD, Schmidt-Traub G, Mazzucato M, Messner D, Nakicenovic N, Rockström J. Six transformations to achieve the sustainable development goals. Nature sustainability. 2019;2(9):805-14.
26. Fonseca LM, Domingues JP, Dima AM. Mapping the sustainable development goals relationships. Sustainability. 2020;12(8):3359.
27. Siddiqui F, Salam RA, Lassi ZS, Das JK. The intertwined relationship between malnutrition and poverty. Frontiers in Public Health. 2020;8:453.
28. Rah JH, Melse-Boonstra A, Agustina R, van Zutphen KG, Kraemer K. The Triple Burden of Malnutrition Among Adolescents in Indonesia. SAGE Publications Sage CA: Los Angeles, CA; 2021. p. S4-S8.
29. Luo H, Zyba SJ, Webb P. Measuring malnutrition in all its forms: An update of the net state of nutrition index to track the global burden of malnutrition at country level. Global Food Security. 2020;26:100453.
30. Kumar P, Chauhan S, Patel R, Srivastava S, Bansod DW. Prevalence and factors associated with triple burden of malnutrition among mother-child pairs in India: a study based on National Family Health Survey 2015–16. BMC Public Health. 2021;21(1):1-12.
31. Sunuwar DR, Singh DR, Pradhan PMS. Prevalence and factors associated with double and triple burden of malnutrition among mothers and children in Nepal: evidence from 2016 Nepal demographic and health survey. BMC Public Health. 2020;20(1):1-11.

32. Ahinkorah BO, Amadu I, Seidu A-A, Okyere J, Duku E, Hagan Jr JE, et al. Prevalence and factors associated with the triple burden of malnutrition among mother-child pairs in Sub-Saharan Africa. Nutrients. 2021;13(6):2050.
33. Kumar P, Chauhan S, Patel R, Srivastava S, Bansod DW. Prevalence and factors associated with triple burden of malnutrition among mother-child pairs in India: a study based on National Family Health Survey 2015–16. BMC Public Health. 2021;21:1-12.
34. Popkin BM, Corvalan C, Grummer-Strawn LM. Dynamics of the double burden of malnutrition and the changing nutrition reality. The Lancet. 2020;395(10217):65-74.
35. Christian AK, Dake FA. Profiling household double and triple burden of malnutrition in sub-Saharan Africa: Prevalence and influencing household factors. Public Health Nutrition. 2022;25(6):1563-76.
36. Wong C, Zalilah M, Chua E, Norhasmah S, Chin Y, Siti Nur'Asyura A. Double-burden of malnutrition among the indigenous peoples (Orang Asli) of Peninsular Malaysia. BMC Public Health. 2015;15(1):1-9.
37. Villena-Esponera MP, Moreno-Rojas R, Molina-Recio G. Food insecurity and the double burden of malnutrition of indigenous refugee Épera Siapidara. Journal of immigrant and minority health. 2019;21(5):1035-42.
38. Tiwari N. The Influence of Single Parent Environment on Children's Learning and Development.
39. Molitoris J. Breastfeeding during pregnancy and its association with childhood malnutrition and pregnancy loss in low-and middle-income countries. Lund Papers in Economic Demography. 2018;2018(3):1-81.
40. Raihana S, Alam A, Huda TM, Dibley MJ. Factors associated with delayed initiation of breastfeeding in health facilities: secondary analysis of Bangladesh demographic and health survey 2014. International Breastfeeding Journal. 2021;16(1):1-13.
41. Belachew A. Timely initiation of breastfeeding and associated factors among mothers of infants age 0–6 months old in Bahir Dar City, Northwest, Ethiopia, 2017: a community based cross-sectional study. International breastfeeding journal. 2019;14(1):1-6.
42. Saaka M, Hammond AY. Caesarean section delivery and risk of poor childhood growth. Journal of nutrition and metabolism. 2020;2020.
43. Pekmez CT, Dragsted LO, Brahe LK. Gut microbiota alterations and dietary modulation in childhood malnutrition–the role of short chain fatty acids. Clinical Nutrition. 2019;38(2):615-30.
44. Kibria A, Muhammed G, Swasey K, Hasan MZ, Sharmeen A, Day B. Prevalence and factors associated with underweight, overweight and obesity among women of reproductive age in India. Global health research and policy. 2019;4(1):1-12.
45. Sekiyama M, Jiang HW, Gunawan B, Dewanti L, Honda R, Shimizu-Furusawa H, et al. Double burden of malnutrition in rural West Java: household-level analysis for father-child and mother-child pairs and the association with dietary intake. Nutrients. 2015;7(10):8376-91.
46. Liguori J, Trübswasser U, Pradeilles R, Le Port A, Landais E, Talsma EF, et al. How do food safety concerns affect consumer behaviors and diets in low-and middle-income countries? A systematic review. Global Food Security. 2022;32:100606.
47. Drammeh W, Hamid NA, Rohana A. Determinants of household food insecurity and its association with child malnutrition in Sub-Saharan Africa: A review of the literature. Current Research in Nutrition and Food Science Journal. 2019;7(3):610-23.

48. Serbesa ML, Iffa MT, Geleto M. Factors associated with malnutrition among pregnant women and lactating mothers in Miesso Health Center, Ethiopia. European Journal of Midwifery. 2019;3.

49. Bhavadharini B, Anjana RM, Deepa M, Jayashree G, Nrutya S, Shobana M, et al. Gestational weight gain and pregnancy outcomes in relation to body mass index in Asian Indian women. Indian Journal of Endocrinology and Metabolism. 2017;21(4):588.

50. Sinha RK, Dua R, Bijalwan V, Rohatgi S, Kumar P. Determinants of stunting, wasting, and underweight in five high-burden pockets of four Indian states. Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine. 2018;43(4):279.

51. Pal A, Manna S, Dalui R, Mukhopadhyay R, Dhara PC. Undernutrition and associated factors among children aged 5–10 years in West Bengal, India: a community-based cross-sectional study. Egyptian Pediatric Association Gazette. 2021;69(1):1-12.

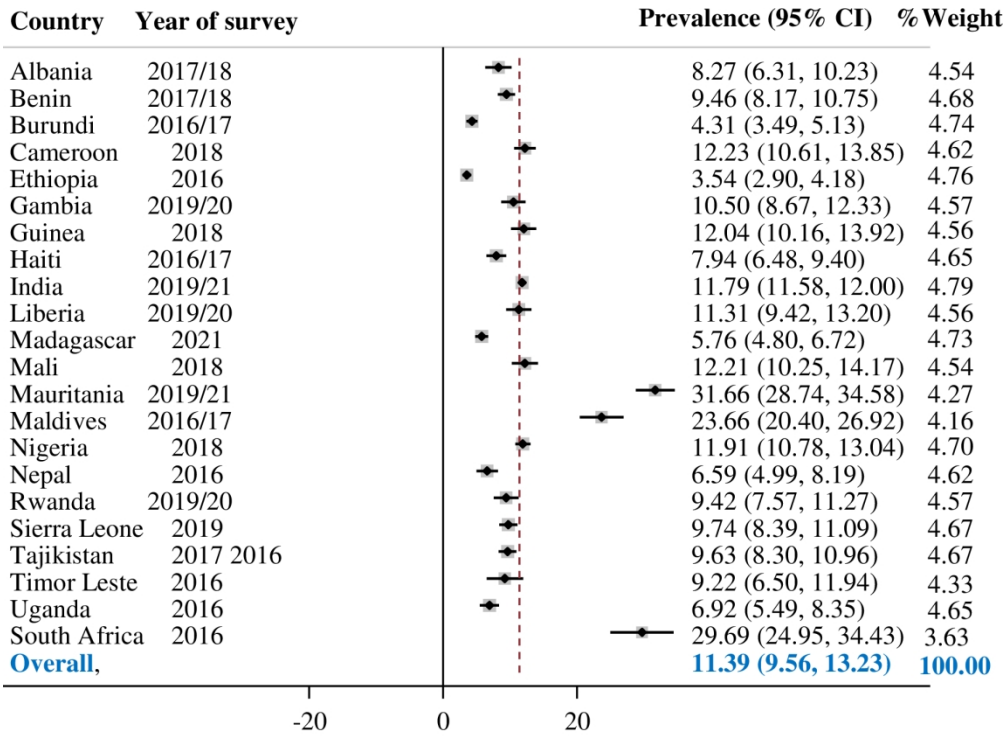
52. Anuradha R, Sivanandham R, Salome SD, Francis R, Roopa D, Sampavi S, et al. Nutritional status of children aged 3-6 years in a rural area of Tamilnadu. Journal of clinical and diagnostic research: JCDR. 2014;8(10):JC01.

53. Hawkes S, Buse K. Gender and global health: evidence, policy, and inconvenient truths. The Lancet. 2013;381(9879):1783-7.

54. Thurstans S, Opondo C, Seal A, Wells J, Khara T, Dolan C, et al. Boys are more likely to be undernourished than girls: a systematic review and meta-analysis of sex differences in undernutrition. BMJ global health. 2020;5(12):e004030.

55. Asfaw M, Wondaferash M, Taha M, Dube L. Prevalence of undernutrition and associated factors among children aged between six to fifty nine months in Bule Hora district, South Ethiopia. BMC Public health. 2015;15(1):1-9.

56. Nagarkar AM, Kulkarni SS. Obesity and its effects on health in middle-aged women from slums of Pune. Journal of Mid-life Health. 2018;9(2):79.



NOTE: Weights are from random-effects model

161x123mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2, 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7,8
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8,9
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	*9*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10/12
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	12/15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Triple burden of malnutrition among mother-child pairs in low and middle-income countries: A cross-sectional study

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Abstract

Objective: This study aimed to assess the prevalence and determinants of the triple burden of malnutrition among mother-child pairs in low-and middle-income countries.

Design: Cross-sectional study

Setting: Low-and middle-income countries

Participants: Women and children

Primary outcome: Triple burden of malnutrition (overweight/obese mother with undernourished and anemic under 5 years child)

Methods: Data for this study were drawn from recent 22 low and middle-income countries Demographic and Health Surveys (DHSs). A total weighted sample of 116,795 mother-child pairs was included in the study. STATA version 14.2 was used to clean, code and analyze the data. Multilevel logistic regression was employed to identify factors associated with the problem. Adjusted odds ratio with 95% CI and a P value <0.05 was reported to indicate statistical association. Model fitness and comparison were done using ICC, MOR, PCV, and deviance.

Result: The pooled prevalence of the triple burden of malnutrition among mother-child pairs was 11.39%. It showed statistically significant positive associations with mothers aged ≥35 years (AOR=2.25,95%CI 2.08-2.44), family size >10 (AOR=1.17,95%CI 1.08-1.26), delivery by CS (AOR=1.93,95%CI 1.83-2.03), the richest household (AOR=1.72,95%CI 1.56-1.88), grand multiparous (AOR=1.62, 95% CI 1.46-1.81), age of child 36-47 months (AOR=1.77, 95% CI 1.64-1.90), at a p-value of <0.05. Whereas breastfeeding (AOR=0.94,95%CI 0.89-0.99), married mothers (AOR=0.87,95%CI 0.78-0.96), female children (AOR=0.88,95%CI 0.84-0.92), improved toilet (AOR=0.23,95%CI 0.17-0.29), improved source of drinking water (AOR=0.28,95%CI 0.21-

0.35), rural residents (AOR=0.66,95%CI 0.62-0.69) had a contrasting relationship with the triple burden of malnutrition

Conclusion: About 1 out of 10 households suffer from the triple burden of malnutrition in low and middle-income countries. This study revealed that several maternal, child, household, and community-level factors have a significant impact on the triple burden of malnutrition among mother-child pairs.

Keywords: Triple burden, mother-child pairs, malnutrition, low and middle-income countries.

Strengths and limitations of this study

- The findings were supported by large datasets covering 22 LMICs.
- We employed multilevel analysis which is an appropriate methodology for such data
- The data were collected using a common internationally acceptable methodological procedure.
- DHS used a cross-sectional survey design, and the causal relationship between the triple burden of malnutrition and the independent variables cannot be established.
- We didn't include important covariates such as dietary intake, physical activity level, or comorbidities as the DHS did not collect information on these variables

Background

The triple burden of malnutrition, which is the coexistence of overnutrition, undernutrition, and micronutrient deficiencies is increasing in low and middle-income countries (LMICs) (1). The World Health Organization (WHO) characterized overnutrition (Obesity and overweight) as a pandemic of a major public health concern due to the increased frequency of the problem in many countries (2). It is ranked as the sixth leading cause of disability-adjusted life years (DALYs) and accounts for approximately 4 million people dying each year worldwide (3-5). Several previous studies have shown that following marked dietary change, obesity/overweight is increasing more rapidly in LMICs compared to higher-income countries (6, 7).

Similarly, undernutrition continues to be a major public health concern throughout the developing world (8, 9). Nearly half of all deaths in children under 5 are attributable to undernutrition and it encompasses wasting, stunting, underweight, and micronutrient deficiencies (anemia) (10, 11). Despite stunting having declined steadily, faster progress is needed to reach the 2030 target (12, 13). Wasting and underweight persisting at alarming rates, require a reversal in trajectory if the 2030 target is to be achieved (14). Since 2000, a significant reduction in the prevalence of anemia in children under five has been observed in many LMICs (15). Children are more vulnerable to inadequate pre-natal, infant, and young child nutrition, particularly in resource-constrained settings (16, 17). Endorsing early childhood feeding best practices is crucial to improve the health of children (18).

Malnutrition has a tremendous negative impact on the normal functioning of every organ system (19). It can cause permanent, widespread damage to a child's growth, development, and well-being (20). Scientific evidence has shown that malnutrition in children is associated with poorer school performance, increased susceptibility to infections, and slow recovery from illness (21, 22).

Maternal malnutrition increases the risk of poor pregnancy outcomes including obstructed labor, premature or low-birth-weight babies, and postpartum hemorrhage (23, 24). To reduce the problem the United Nations (UN) adopted the Sustainable Development Goals (SDGs), targeted to end poverty in all its forms everywhere (SDG 1), end hunger, achieve food security, improve nutrition, promote sustainable agriculture (SDG 2), ensure healthy lives, and promote well-being for all at all ages (SDG 3) (25, 26).

Previous literature recognized the basic and underlying causes of malnutrition including the environmental, economic, and sociopolitical contextual factors, with poverty having a central role (11, 27-29). The triple burden of malnutrition among mother-child pairs is a relatively new issue and only a few country-based studies explored the problem which couldn't give a panoramic view of the problem in LMICs (30-32). Given the persistent and high levels of the problem in these countries, there is a strong need for action. To design and deliver effective interventions adequate understanding of the socioeconomic, environmental, and cultural factors is highly important. Besides if the SDG targets are to be met, coordinated action is required toward not only sustaining current rates of decline but also accelerating progress. Therefore, the objective of this study was to assess the prevalence of the triple burden of malnutrition among mothers and children and the potential factors associated with it in low and middle-income countries.

Materials and methods

Study design, setting, and period

The present study is based on 22 low and middle-income countries that have had Demographic and Health Surveys (DHS) from 2016-2020. The DHS used a cross-sectional survey study design to collect data and provide population and health indicators at the national level. The list of those countries and the respective year of surveys is provided in Table 1.

Table 1. Study setting and year of surveys

Country	Year of survey	Region
Albania	2017/18	Southeastern Europe
Benin	2017/18	West Africa
Burundi	2016/17	East-central Africa
Cameroon	2018	West-central Africa
Ethiopia	2016	East Africa
Gambia	2019/20	West Africa
Guinea	2018	West Africa
Haiti	2016/17	Caribbean
India	2019/21	South Asia
Liberia	2019/20	West Africa
Madagascar	2021	East Africa
Mali	2018	West Africa
Mauritania	2019/21	Northwest Africa
Maldives	2016/17	South Asia
Nigeria	2018	West Africa
Nepal	2016	South Asia
Rwanda	2019/20	East Africa
Sierra Leone	2019	West Africa
Tajikistan	2017	Central Asia
Timor Leste	2016	South Asia
Uganda	2016	East Africa
South Africa	2016	South Africa

Data source and sampling procedure

The current analysis was based on pooled data from DHSs in 22 LMICs. These are nationally representative surveys that collect data on reproductive, maternal, neonatal, child health, and nutrition in LMIC. The surveys are similarly designed that used standardized questionnaires and data collection procedures, allowing therefore comparability of results. The survey employed a two-stage cluster sampling technique. In the first stage, the selection of proportional clusters/enumeration areas was performed using each country's most recent population and housing census as a sampling frame. In the second stage, a systematic selection of households from the newly created cluster was performed. A detailed description of the DHS sampling design and data collection procedures has been found in each country's DHS report. The study population for

this study was mother-child pairs. Weighting was done using the complex sample design weighting and the "svyset" Stata command was applied. Variables v005 (sampling weight), v021 (primary sampling unit), and v023 (stratification used in sample design) were used, and as the result, a total weighted sample of 116,795 mother-child pairs was included in the analysis.

Definition of variables

Outcome variable:

The triple burden of malnutrition was the outcome variable of this study where the mother was overweight/obese and children under 5 years of age were undernourished and anemic (31, 33). At the same household level, first, we created four different categories of malnutrition such as overweight/obese mother and stunted child, overweight/obese mother and wasted child, overweight/obese mother and underweight child, and overweight/obese mother and anemic child. Then we further combined overweight/obese mothers, undernourished children, and anemic children to generate the triple burden of malnutrition. Categorization was made based on height-for-age z-score (HAZ), standard deviations (SD), weight-for-height z-score (WHZ), weight-for-age z-score (WAZ), hemoglobin level, and body mass index (BMI).

Stunting dichotomized and coded into 0=Not stunted (HAZ -2SD and above) & 1= Stunted (HAZ < -2SD);

Wasting dichotomized and coded into 0=Not wasted (WHZ-2SD to +2SD) and 1=Wasted (WHZ < -2SD);

Underweight dichotomized and coded into 0= Not underweight (WHZ-2SD and above) & 1= Underweight (WAZ < -2SD);

Child anemia dichotomized and coded into 0= Not anemic (hemoglobin level > 11 g/dl), & 1= Anemic (hemoglobin level < 11 g/dl);

Mother's BMI dichotomized and coded into 0= Normal (18.5–24.9 kg/m2) & 1= Overweight/Obese (≥25 kg/m2)

The triple burden of malnutrition was dichotomized and coded into 0= NO (not overweight/obese mother and not undernourished child plus not anemic child, and 1= YES (overweight/obese mother and undernourished child plus anemic child)

An undernourished child is a child who is stunted or wasted or underweight.

Independent variables:

Based on previous works of literature and the likelihood of influencing the outcome of interest, several explanatory variables including the age of mothers, mother's education, marital status, current breastfeeding, delivery by cesarean section, family size, wealth index, media access, parity, age of the child, sex of the child, type of toilet facility, source of drinking water, residence and distance to health facility were considered.

Statistical analyses

We append the dataset of each country to generate pooled data. The data extraction, coding, and analysis were carried out using STATA software version 14.2. We weighted the sample to restore the representativeness of the sample so that the total sample looks like the country's actual population. Due to the hierarchical nature of the DHS, the multilevel analysis was fitted to identify significantly associated factors. Four models were fitted; the null model (with no predictors), model I (adjusted for individual-level variables only), model II (adjusted for community-level variables only), and model III (model adjustment for both individual and community-level variables simultaneously). Adjusted OR (AOR) with 95% CI and $p<0.05$ were used to determine significant predictors. Model fitness and comparison were done using Intraclass Correlation

Coefficient (ICC), Proportional Change in Variance (PCV), Median Odds Ratio (MOR), the Likelihood Ratio test (LR), and deviance computed.

Patient and public involvement statement

As our study used secondary analysis of DHS data, participants and the public were not involved in the study design or planning of the study. The study participants were not consulted to interpret the results and write or editing of this document for readability or accuracy.

Results

Demographics and socioeconomic characteristics

A total of 116,795 mother-child pairs were included in the study. Over half (56.48%) of mothers were in the age category of 25-34 years. About 22.98% of mothers were illiterate and the majority (46.39%) had attended secondary education. Approximately 95.73% of mothers were married and 62.89% were currently breastfeeding. About 20.33% and 21.21% of the households were in the low wealth quintile of poorest and poorer respectively. Over a quarter (27.62%) of the families had never been exposed to any type of media. The majority of the children (32.59%) were aged ≤12 months. A large proportion (83.60%) of the households had improved sources of drinking water and almost two-thirds (67.02%) of the households had improved toilet facilities. Almost three fourth (71.03%) of participants lived in rural areas and for over a quarter (27.42%) of those participants, the distance to access health facilities was a big problem (**Table 2**).

Table 2. Socio-demographic characteristics of the study participants

Variables	Categories	Unweighted frequency (%)	Weighted frequency (%)
Age of mothers	15-24	34,983 (29.05)	35,918 (30.75)
	25-34	68,386 (56.78)	65,971 (56.48)

	≥35	17,073 (14.18)	14,906 (12.76)
Mothers education	No education	27,995 (23.24)	26,845 (22.98)
	Primary education	19,684 (16.34)	18,633 (15.95)
	Secondary	57,008 (47.33)	54,185 (46.39)
	Higher	15,755 (13.08)	17,131 (14.67)
Mothers marital status	Not in union	5,583 (4.64)	4,987 (4.27)
	Married	114,859 (95.36)	111,807 (95.73)
Currently breastfeeding	No	44,160 (36.66)	43,338 (37.11)
	Yes	76,282 (63.34)	73,457 (62.89)
Delivery by cesarean section	No	99,291 (82.49)	93,974 (80.51)
	Yes	21,077 (17.51)	22,748 (19.49)
Family size	≤5	56,365 (46.80)	53,677 (45.96)
	6-10	54,605 (45.34)	53,258 (45.60)
	>10	9,472 (7.86)	9,859 (8.44)
Wealth index	Poorest	28,097 (23.33)	23,749 (20.33)
	Poorer	27,352 (22.71)	24,774 (21.21)
	Middle	24,741 (20.54)	24,330 (20.83)
	Richer	22,180 (18.42)	23,880 (20.45)
	Richest	18,072 (15.00)	20,061 (17.18)
Media access	No	33,942 (28.18)	32,256 (27.62)
	Yes	86,500 (71.82)	84,539 (72.38)
Parity	Primiparous	36,241 (30.09)	35,333 (30.25)
	Multiparous	76,092 (63.18)	73,823 (63.21)
	Grand Multiparous	8,109 (6.73)	7,639 (6.54)
Age of child	≤12	38,959 (32.35)	38,059 (32.59)
	13-23	25,382 (21.07)	24,819 (21.25)
	24-35	22,208 (18.44)	21,478 (18.39)
	36-47	17,948 (14.90)	17,204 (14.73)
	48-59	15,945 (13.24)	15,234 (13.04)
Sex of child	Male	63,660 (52.86)	62,008 (53.09)
	Female	56,782 (47.14)	54,787 (46.91)
Type of toilet facility	Unimproved	37,519 (31.15)	38,518 (32.98)
	Improved	82,923 (68.85)	78,277 (67.02)
Source of drinking water	Unimproved	20,959 (17.40)	19,159 (16.40)
	Improved	99,483 (82.60)	97,636 (83.60)
Residence	Urban	28,722 (23.85)	33,838 (28.97)
	Rural	91,720 (76.15)	82,957 (71.03)
Distance to a health facility	No problem	84,605 (70.25)	84,776 (72.58)
	Big problem	35,837 (29.75)	32,019 (27.42)

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198 **Prevalence of triple burden of malnutrition**

In 22 low and middle-income countries, the pooled prevalence of the triple burden of malnutrition among mother-child pairs was found at 11.39 % (95% CI 9.56%, 13.23%). Ethiopia has the lowest (3.54 %) prevalence of triple burden while Mauritania (31.66%) bears the highest (**Figure 1**).

Fig 1. The pooled prevalence of the triple burden of malnutrition

Multilevel analyses

Random parameter estimation and model selection

Based on the result of random effect analysis, the ICC of the null model was 0.30, indicating that 30% of the total variability in triple burden prevalence was attributable to between-cluster variability, while about 70% was due to individual differences. The null model MOR was 3.04, which indicates that a mother/child from a cluster with a high triple burden prevalence has a 3.04 times higher probability of being malnourished than a mother/child from a cluster with a lower prevalence. Model III was the best-fitted model since it has the highest log likelihood (-91665) and the lowest deviance (183,330) value **(Table 3)**.

Factors associated with the triple burden of malnutrition (Fixed effects)

The triple burden of malnutrition was statistically significant with mothers aged 25-34 years (AOR=1.54, 95% CI 1.45 - 1.63), ≥35 years (AOR=2.25, 95% CI 2.08 - 2.44), mothers attended secondary education (AOR=1.08, 95% CI 1.02-1.15), family size >10 (AOR=1.17, 95% CI 1.08 - 1.26), delivery by CS (AOR=1.93, 95% CI 1.83 - 2.03), the richer household (AOR=1.63, 95% CI 1.49 - 1.76), the richest household (AOR=1.72, 95% CI 1.56 - 1.88), multiparous (AOR=1.42, 95% CI 1.34 - 1.49), grand multiparous (AOR=1.62, 95% CI 1.46 - 1.81), age of child 36-47 months (AOR=1.77, 95% CI 1.64 - 1.90), age of child 48-59 (AOR=1.51, 95% CI 1.39 - 1.64), breastfeeding (AOR=0.94, 95% CI 0.89 - 0.99), married mothers (AOR=0.87, 95% CI 0.78 - 0.96),

female children (AOR=0.88, 95% CI 0.84 - 0.92), improved toilet facility (AOR=0.23, 95% CI 0.17 - 0.29), improved source of drinking water (AOR=0.28, 95% CI 0.21 - 0.35), rural residents (AOR=0.66, 95% CI 0.62 - 0.69) at a p-value of <0·05 **(Table 3)**.

Table 3. Multivariable multilevel logistic regression analysis of the triple burden of malnutrition.

Variables	Categories	Null model	Model I AOR 95% CI	Model II AOR 95% CI	Model III AOR 95% CI
Age of mothers	15-24		1.00		1.00
	25-34		1.54 (1.46 - 1.63)**	—	1.54 (1.45 - 1.63)**
	≥35		2.28 (2.11 - 2.47)**	—	2.25 (2.08 - 2.44)**
Mothers education	No education		1.00		1.00
	Primary education		1.04 (0.97 - 1.12)	—	1.04 (0.97 - 1.12)
	Secondary		1.08 (1.01 - 1.15)*	—	1.08 (1.02 - 1.15)*
	Higher		0.94 (0.86 - 1.02)	—	0.94 (0.86 - 1.02)
Mothers marital status	Not in union		1.00		1.00
	Married		0.83 (0.75 - 0.93)*	—	0.87 (0.78 - 0.96)**
Currently breastfeeding	No		1.00		1.00
	Yes		0.92 (0.87 - 0.97)*	—	0.94 (0.89 - 0.99)*
Delivery by CS	No		1.00		1.00
	Yes		1.94 (1.84 - 2.04)**	—	1.93 (1.83 - 2.03)**
Family size	≤5		1.00		1.00
	6-10		1.00 (0.97 - 1.08)	—	1.01 (0.98 - 1.08)
	>10		1.14 (1.06 - 1.24)**	—	1.17 (1.08 - 1.26)**
Wealth index	Poorest		1.00		1.00
	Poorer		1.41 (1.31 - 1.52)**	—	1.38 (1.28 - 1.49)**
	Middle		1.60 (1.48 - 1.73)**	—	1.49 (1.38 - 1.62)**
	Richer		1.86 (1.72 - 2.02)**	—	1.63 (1.49 - 1.76)**
	Richest		2.15 (1.97 - 2.35)**	—	1.72 (1.56 - 1.88)**
Media access	No		1.00		1.00
	Yes		1.01 (0.98 - 1.08)	—	1.02 (0.99 - 1.11)
Parity	Primiparous		1.00		1.00
	Multiparous		1.42 (1.34 - 1.50)**	—	1.42 (1.34 - 1.49)**
	Grand Multiparous		1.61 (1.44 - 1.79)**	—	1.62 (1.46 - 1.81)**
Age of child	≤12		1.00		1.00
	13-23		1.41 (1.32 - 1.50)**	—	1.41 (1.32 - 1.50)**
	24-35		1.62 (1.52 - 1.73)**	—	1.63 (1.53 - 1.74)**
	36-47		1.75 (1.62 - 1.89)**	—	1.77 (1.64 - 1.90)**
	48-59		1.50 (1.38 - 1.62)**	—	1.51 (1.39 - 1.64)**
Sex of child	Male		1.00		1.00
	Female		0.88 (0.84 - 0.92)**	—	0.88 (0.84 - 0.92)**

Type of toilet facility	Unimproved		1.00		1.00
	Improved		0.24 (0.18 - 1.31)	—	0.23 (0.17 - 0.29)**
Source of drinking water	Unimproved		1.00		1.00
	Improved		0.21 (0.16 - 0.28)	—	0.28 (0.21 - 0.35)**
Community-level variables					
Residence	Urban			1.00	1.00
	Rural		—	0.49 (0.46 - 0.52)**	0.66 (0.62 - 0.69)**
Distance to a health facility	No problem			1.00	1.00
	Big problem		—	0.87 (0.82 - 0.91)**	0.94 (0.89 - 0.98)**
Random effect					
	Variance	1.40	1.24	1.31	1.23
	ICC	0.30	0.27	0.28	0.27
	MOR	3.04	2.88	2.96	2.85
	PCV	Reff	11.42	6.43	12.14
Model comparison					
	Log likelihood ratio	-100585	-92108	-97815	-91665
	Deviance	201,170	184,216	195,630	183,330

* = P-value < 0.05, ** = P-value < 0.01,
ICC = Inter cluster correlation coefficient, MOR =Median odds ratio, PCV = proportional change in variance. AOR=adjusted odds ratio; CI= confidence interval,

Discussion

LMICs are increasingly facing the triple burden of malnutrition where women and children are among the hardest hit by the problem (34, 35). This study assessed the triple burden of malnutrition (co-occurrence of undernutrition, overweight/obesity, and anemia among mother-child pairs) in the same household, using nationally representative data in LMICs. The result showed that the pooled prevalence of triple burden was 11.39 % (95% CI 9.56%, 13.23%); Ethiopia had the lowest (3.54 %) prevalence while Mauritania (31.66%) had the highest. The variation among countries could be attributed to differences in socio-economic status, food environment, physical activity, genetic factors, health care system strength, national policy, and political commitments.

The study revealed that several maternal, child, household, and community-level factors have a significant impact on the triple burden of malnutrition among mother-child pairs. It has found a parallel correlation between the triple burden of malnutrition and maternal age. The odds of being

malnourished increase as the age of the mother increases. This is in agreement with previous studies where older mothers bear the highest risk compared to younger ones (31, 36). The possible explanation could be because of reduced physical activity, less energy requirement, and hormonal changes among older mothers. Similarly, mothers who have attended secondary education were more likely to be malnourished (31). A plausible explanation for this could be the shifts from manual labor to more sedentary occupations and the related decline in physical activity.

Being married reduced the risk of the triple burden of malnutrition. Partners together could generate more money, reduce food insecurity, and tend to take better care of themselves and their children. It is been reported that children in single-parent households suffered from undernutrition significantly more than children brought up by both parents (37, 38). Likewise, this study revealed breastfeeding reduced the triple burden of malnutrition. Breastfeeding plays a vital role in the prevention of different forms of childhood malnutrition (39). However, delivery by cesarean section (C-section) delays the timely initiation of breastfeeding and pre-lacteal feeding (40). Previous studies have reported that C-section increases maternal obesity and negatively affect the breastfeeding of children, which results in malnutrition (41, 42). Moreover, malnutrition in children is related to gut microbiota alteration and C-section contributes to microbial alterations in the small intestine (43).

Our study revealed a parallel relationship between the household wealth quintiles and the triple burden of malnutrition. As household income increases, the odds of malnutrition increase (30, 44). High income could increase the purchasing power for food, influencing the type of foods consumed and the intake of prepared or processed food (34). Economic growth and the food industry's rapid penetration into the market have resulted to depend on energy-dense and nutrient-

poor foods (45). In recent years, the dietary preference in LMICs has changed as the food environment is dominated by media advertising, and relatively cheap, energy-dense foods (46).

The odds of the triple burden of malnutrition were higher in a household with a family size >10. A plausible explanation is that in a household with a large family, providing optimum nutritious food to all the family members and children could be difficult (47, 48). Moreover giving proper care and time to children and the family could be unlikely and this could lead to malnutrition. Likewise, parity was found to be a determinant of the triple burden of malnutrition. Higher parity increased the odds of malnutrition. The possible explanation could be that women could gain weight during pregnancy, and weight loss might not occur in the post-partum period which could lead to child malnutrition. (49).

The present study revealed that child age and sex were significant factors for malnutrition. Older under-five children were more likely to be malnourished compared to younger ones (50). A previous study (51) revealed that there was an increased frequency of parasite infection in older children leading to a higher prevalence of malnutrition compared to the younger ones. In addition, gender was found a significant determinant of malnutrition where a female child was less likely to be malnourished (52). The cause of the gender gap in malnutrition is unknown, however, some studies argued that male children are known to be more vulnerable than females to diseases including lower respiratory infections, diarrhoeal diseases, malaria, and preterm birth. Those diseases have been reported as factors for undernutrition among young male children (53, 54). Others also claimed that boys are more vulnerable to environmental problems while playing, such as exposure to toxins and air pollution than girls (55).

Being rural residents was associated with lower odds of the triple burden of malnutrition. The urban-rural difference could be attributable to factors including access to different food types,

overcrowding, concurrent disease, and sedentary lifestyles. Previous studies depicted that urbanization affects the way of life, access to processed and junk foods could exacerbate malnutrition among women and children (30, 56).

Our study has some strengths and limitations. It used large nationally representative samples with appropriate statistical modeling. The use of large nationally representative data and multilevel analysis helps to provide more robust estimates of observed associations as well as enhance the generalizability of the results. Despite the strengths, this study used cross-sectional data, which did not indicate a temporal relationship between the factors and triple burden. No important covariates, such as dietary intake, physical activity level, comorbidities, and nutrition status during pregnancy, were incorporated into the study as the DHS did not provide a complete record of these variables.

Conclusions and recommendations

About 1 out of 10 households suffer from the triple burden of malnutrition in low and middle-income countries. This study revealed that several maternal, child, household, and community-level factors have a significant impact on the triple burden of malnutrition among mother-child pairs. The triple burden requires the governments, the scientific and medical communities, and the industry's efforts in changing dietary and lifestyle habits to address all forms of malnutrition and should focus on women's nutrition to break the intergenerational triple burden of malnutrition.

Abbreviations

AOR, Adjusted Odds Ratio; DHSs, Demographic and Health Surveys; ICC, Intra cluster correlation coefficient; LMICs, low and middle-income countries; MOR, median odds ratio; PCV, a proportional change in variance; SDGs, Sustainable Development Goals; WHO, World Health Organization

Declarations

Ethics approval and consent to participate

Permission to access the data was obtained from the measure DHS program (http://www.dhsprogram.com) via online request. The website and the data used were publicly available with no personal identifier. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

Data are available online in a public, open-access repository (www.measuredhs.com/data).

Competing interests

The authors declare that they have no competing interests.

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Author Contributions

Conceptualization: DC. Study design: DC, DGB, MWM, AAK, AZA, MHA, NWT, and FMA. Execution: DC, DGB, MWM, AAK, AZA, MHA, NWT, and FMA. Acquisition of the data: DC, DGB, MWM, AAK, AZA, MHA, NWT, and FMA. Analysis and interpretation: DC, DGB, MWM, AAK, AZA, MHA, NWT, and FMA. Writing: DC, DGB, MWM, AAK, AZA, MHA, NWT, and FMA. Review and editing: DC, DGB, MWM, AAK, AZA, MHA, NWT, and FMA.

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References

1. Meenakshi J. Trends and patterns in the triple burden of malnutrition in India. Agricultural Economics. 2016;47(S1):115-34.
2. Hepatology TLG. Obesity: another ongoing pandemic. 2021. p. 411.
3. Organization WH. Diet, nutrition, and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation: World Health Organization; 2003.
4. Tabarés Seisdedos R. Health effects of overweight and obesity in 195 countries over 25 years. New England Journal of Medicine, 2017, vol 377, num 1, p 13-27. 2017.
5. Dai H, Alsalhe TA, Chalghaf N, Riccò M, Bragazzi NL, Wu J. The global burden of disease attributable to high body mass index in 195 countries and territories, 1990–2017: An analysis of the Global Burden of Disease Study. PLoS medicine. 2020;17(7):e1003198.
6. Ford ND, Patel SA, Narayan KV. Obesity in low-and middle-income countries: burden, drivers, and emerging challenges. Annual review of public health. 2017;38:145-64.
7. Mahumud RA, Sahle BW, Owusu-Addo E, Chen W, Morton RL, Renzaho A. Association of dietary intake, physical activity, and sedentary behaviours with overweight and obesity among 282,213 adolescents in 89 low and middle income to high-income countries. International Journal of Obesity. 2021;45(11):2404-18.
8. Heidkamp RA, Piwoz E, Gillespie S, Keats EC, D'Alimonte MR, Menon P, et al. Mobilising evidence, data, and resources to achieve global maternal and child undernutrition targets and the Sustainable Development Goals: an agenda for action. The Lancet. 2021;397(10282):1400-18.
9. Osendarp S, Akuoku JK, Black RE, Headey D, Ruel M, Scott N, et al. The COVID-19 crisis will exacerbate maternal and child undernutrition and child mortality in low-and middle-income countries. Nature Food. 2021;2(7):476-84.
10. World Health Organisation Fact Sheets—Malnutrition. Available online: https://www.who.int/news-room/fact-sheets/detail/malnutrition (accessed on 26 Nov 2022).
11. Adepoju AA, Allen S. Malnutrition in developing countries: nutrition disorders, a leading cause of ill health in the world today. Paediatrics and Child Health. 2019;29(9):394-400.
12. Sunguya BF, Zhu S, Mpembeni R, Huang J. Trends in prevalence and determinants of stunting in Tanzania: an analysis of Tanzania demographic health surveys (1991–2016). Nutrition Journal. 2019;18(1):1-13.
13. Yang YY, Kaddu G, Ngendahimana D, Barkoukis H, Freedman D, Lubaale YA, et al. Trends and determinants of stunting among under-5s: evidence from the 1995, 2001, 2006 and 2011 Uganda Demographic and Health Surveys. Public health nutrition. 2018;21(16):2915-28.
14. Singh KJ, Chiero V, Kriina M, Alee NT, Chauhan K. Identifying the trend of persistent cluster of stunting, wasting, and underweight among children under five years in northeastern states of India. Clinical Epidemiology and Global Health. 2022;18:101158.
15. Organization. WH. WHO Global Anaemia Estimates, 2021 Edition. Anaemia in Women and Children. Available online: https://www. who. int/data/gho/data/themes/topics/anaemia_in_women_and_children (accessed on 1 December 2022).

16. Koli HB, Nair MG, Shah MC. Impact of structured pre-natal counselling on early initiation of breast feeding and adherence to exclusive breast feeding: a comparative interventional study. International Journal of Reproduction, Contraception, Obstetrics and Gynecology. 2021;10(7):2699-704.
17. Scott N, Delport D, Hainsworth S, Pearson R, Morgan C, Huang S, et al. Ending malnutrition in all its forms requires scaling up proven nutrition interventions and much more: a 129-country analysis. BMC medicine. 2020;18(1):1-19.
18. Mistry SK, Hossain M, Arora A. Maternal nutrition counselling is associated with reduced stunting prevalence and improved feeding practices in early childhood: a post-program comparison study. Nutrition Journal. 2019;18(1):1-9.
19. Norman K, Haß U, Pirlich M. Malnutrition in older adults—recent advances and remaining challenges. Nutrients. 2021;13(8):2764.
20. Forgie AJ, Drall KM, Bourque SL, Field CJ, Kozyrskyj AL, Willing BP. The impact of maternal and early life malnutrition on health: a diet-microbe perspective. BMC medicine. 2020;18(1):1-15.
21. Kirolos A, Goyheneix M, Eliasz MK, Chisala M, Lissauer S, Gladstone M, et al. Neurodevelopmental, cognitive, behavioural and mental health impairments following childhood malnutrition: a systematic review. BMJ global health. 2022;7(7):e009330.
22. Walson JL, Berkley JA. The impact of malnutrition on childhood infections. Current opinion in infectious diseases. 2018;31(3):231.
23. Castro-Rodríguez DC, Rodríguez-González GL, Menjivar M, Zambrano E. Maternal interventions to prevent adverse fetal programming outcomes due to maternal malnutrition: Evidence in animal models. Placenta. 2020;102:49-54.
24. Desyibelew HD, Dadi AF. Burden and determinants of malnutrition among pregnant women in Africa: A systematic review and meta-analysis. PloS one. 2019;14(9):e0221712.
25. Sachs JD, Schmidt-Traub G, Mazzucato M, Messner D, Nakicenovic N, Rockström J. Six transformations to achieve the sustainable development goals. Nature sustainability. 2019;2(9):805-14.
26. Fonseca LM, Domingues JP, Dima AM. Mapping the sustainable development goals relationships. Sustainability. 2020;12(8):3359.
27. Siddiqui F, Salam RA, Lassi ZS, Das JK. The intertwined relationship between malnutrition and poverty. Frontiers in Public Health. 2020;8:453.
28. Rah JH, Melse-Boonstra A, Agustina R, van Zutphen KG, Kraemer K. The Triple Burden of Malnutrition Among Adolescents in Indonesia. SAGE Publications Sage CA: Los Angeles, CA; 2021. p. S4-S8.
29. Luo H, Zyba SJ, Webb P. Measuring malnutrition in all its forms: An update of the net state of nutrition index to track the global burden of malnutrition at country level. Global Food Security. 2020;26:100453.
30. Kumar P, Chauhan S, Patel R, Srivastava S, Bansod DW. Prevalence and factors associated with triple burden of malnutrition among mother-child pairs in India: a study based on National Family Health Survey 2015–16. BMC Public Health. 2021;21(1):1-12.
31. Sunuwar DR, Singh DR, Pradhan PMS. Prevalence and factors associated with double and triple burden of malnutrition among mothers and children in Nepal: evidence from 2016 Nepal demographic and health survey. BMC Public Health. 2020;20(1):1-11.

32. Ahinkorah BO, Amadu I, Seidu A-A, Okyere J, Duku E, Hagan Jr JE, et al. Prevalence and factors associated with the triple burden of malnutrition among mother-child pairs in Sub-Saharan Africa. Nutrients. 2021;13(6):2050.
33. Kumar P, Chauhan S, Patel R, Srivastava S, Bansod DW. Prevalence and factors associated with triple burden of malnutrition among mother-child pairs in India: a study based on National Family Health Survey 2015–16. BMC Public Health. 2021;21:1-12.
34. Popkin BM, Corvalan C, Grummer-Strawn LM. Dynamics of the double burden of malnutrition and the changing nutrition reality. The Lancet. 2020;395(10217):65-74.
35. Christian AK, Dake FA. Profiling household double and triple burden of malnutrition in sub-Saharan Africa: Prevalence and influencing household factors. Public Health Nutrition. 2022;25(6):1563-76.
36. Wong C, Zalilah M, Chua E, Norhasmah S, Chin Y, Siti Nur'Asyura A. Double-burden of malnutrition among the indigenous peoples (Orang Asli) of Peninsular Malaysia. BMC Public Health. 2015;15(1):1-9.
37. Villena-Esponera MP, Moreno-Rojas R, Molina-Recio G. Food insecurity and the double burden of malnutrition of indigenous refugee Épera Siapidara. Journal of immigrant and minority health. 2019;21(5):1035-42.
38. Tiwari N. The Influence of Single Parent Environment on Children's Learning and Development.
39. Molitoris J. Breastfeeding during pregnancy and its association with childhood malnutrition and pregnancy loss in low-and middle-income countries. Lund Papers in Economic Demography. 2018;2018(3):1-81.
40. Raihana S, Alam A, Huda TM, Dibley MJ. Factors associated with delayed initiation of breastfeeding in health facilities: secondary analysis of Bangladesh demographic and health survey 2014. International Breastfeeding Journal. 2021;16(1):1-13.
41. Belachew A. Timely initiation of breastfeeding and associated factors among mothers of infants age 0–6 months old in Bahir Dar City, Northwest, Ethiopia, 2017: a community based cross-sectional study. International breastfeeding journal. 2019;14(1):1-6.
42. Saaka M, Hammond AY. Caesarean section delivery and risk of poor childhood growth. Journal of nutrition and metabolism. 2020;2020.
43. Pekmez CT, Dragsted LO, Brahe LK. Gut microbiota alterations and dietary modulation in childhood malnutrition–the role of short chain fatty acids. Clinical Nutrition. 2019;38(2):615-30.
44. Kibria A, Muhammed G, Swasey K, Hasan MZ, Sharmeen A, Day B. Prevalence and factors associated with underweight, overweight and obesity among women of reproductive age in India. Global health research and policy. 2019;4(1):1-12.
45. Sekiyama M, Jiang HW, Gunawan B, Dewanti L, Honda R, Shimizu-Furusawa H, et al. Double burden of malnutrition in rural West Java: household-level analysis for father-child and mother-child pairs and the association with dietary intake. Nutrients. 2015;7(10):8376-91.
46. Liguori J, Trübswasser U, Pradeilles R, Le Port A, Landais E, Talsma EF, et al. How do food safety concerns affect consumer behaviors and diets in low-and middle-income countries? A systematic review. Global Food Security. 2022;32:100606.
47. Drammeh W, Hamid NA, Rohana A. Determinants of household food insecurity and its association with child malnutrition in Sub-Saharan Africa: A review of the literature. Current Research in Nutrition and Food Science Journal. 2019;7(3):610-23.

48. Serbesa ML, Iffa MT, Geleto M. Factors associated with malnutrition among pregnant women and lactating mothers in Miesso Health Center, Ethiopia. European Journal of Midwifery. 2019;3.

49. Bhavadharini B, Anjana RM, Deepa M, Jayashree G, Nrutya S, Shobana M, et al. Gestational weight gain and pregnancy outcomes in relation to body mass index in Asian Indian women. Indian Journal of Endocrinology and Metabolism. 2017;21(4):588.

50. Sinha RK, Dua R, Bijalwan V, Rohatgi S, Kumar P. Determinants of stunting, wasting, and underweight in five high-burden pockets of four Indian states. Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine. 2018;43(4):279.

51. Pal A, Manna S, Dalui R, Mukhopadhyay R, Dhara PC. Undernutrition and associated factors among children aged 5–10 years in West Bengal, India: a community-based cross-sectional study. Egyptian Pediatric Association Gazette. 2021;69(1):1-12.

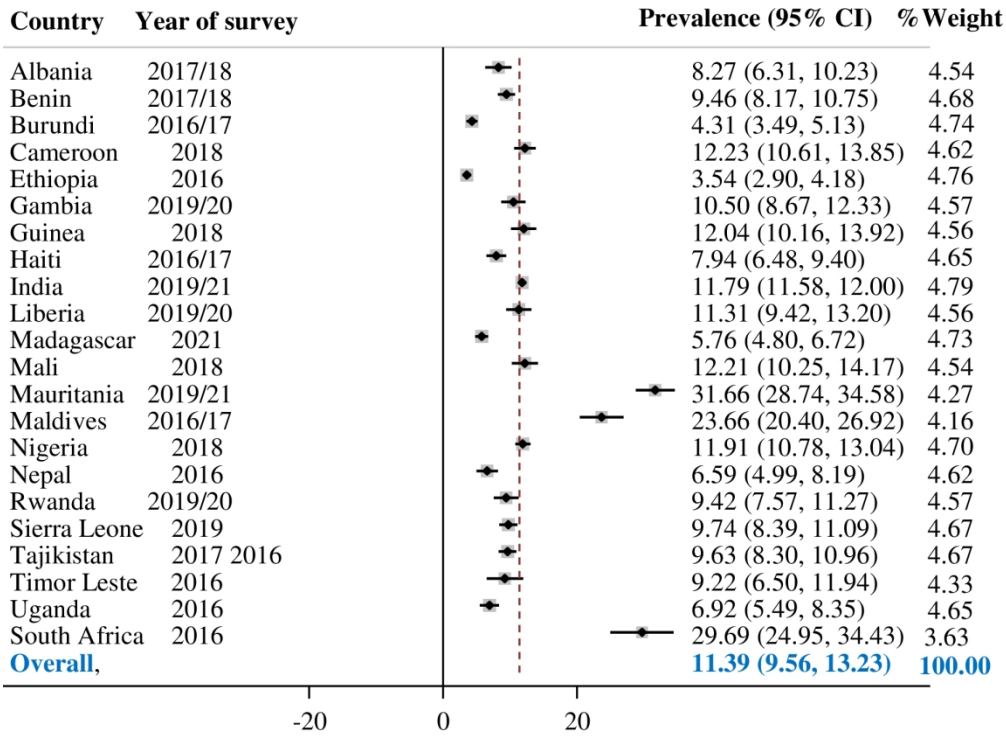
52. Anuradha R, Sivanandham R, Salome SD, Francis R, Roopa D, Sampavi S, et al. Nutritional status of children aged 3-6 years in a rural area of Tamilnadu. Journal of clinical and diagnostic research: JCDR. 2014;8(10):JC01.

53. Hawkes S, Buse K. Gender and global health: evidence, policy, and inconvenient truths. The Lancet. 2013;381(9879):1783-7.

54. Thurstans S, Opondo C, Seal A, Wells J, Khara T, Dolan C, et al. Boys are more likely to be undernourished than girls: a systematic review and meta-analysis of sex differences in undernutrition. BMJ global health. 2020;5(12):e004030.

55. Asfaw M, Wondaferash M, Taha M, Dube L. Prevalence of undernutrition and associated factors among children aged between six to fifty nine months in Bule Hora district, South Ethiopia. BMC Public health. 2015;15(1):1-9.

56. Nagarkar AM, Kulkarni SS. Obesity and its effects on health in middle-aged women from slums of Pune. Journal of Mid-life Health. 2018;9(2):79.



NOTE: Weights are from random-effects model

161x123mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2, 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7,8
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8,9
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	*9*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10/12
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	12/15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.