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Double burden of malnutrition among under-five children in Eastern and Southern African countries

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There is limited evidence on the burden and drivers of the co-occurrence of overweight/obesity and undernutrition at the individual level in low- and middle-income countries. This gap hinders the design of double-duty actions (DDAs) that can effectively address all forms of malnutrition. This multi-country study aimed to determine the magnitude of double burden of malnutrition (DBM) among under five children and identify household and individual level determinants in Eastern and Southern Africa (ESA) countries. We pooled data of 79,394 children aged 6–59 months, collected from Demographic and Health Surveys (DHS) conducted in 12 ESA countries between 2013 and 2016. We identified confounders a *priori*. A random effect logistic regression was performed to identify factors associated with the co-occurrence of Stunting and Overweight (StOw), Overweight and Anemia (OwA), and Stunting Overweight and Anemia (StOwA). The study revealed that the burden of co-occurrence of StOwA, StOw, and OwA among under-five children were 5.38%; 95% confidence interval (CI) (5.00-5.79), 4.04 (95% CI: 3.86–4.23), and 5.72% (95% CI: 5.40–6.04), respectively. South Africa had the highest burden of co-occurrence of StOwA (15.58%) and OwA (22.30%), while Namibia and Burundi had the lowest StOwA (2.19%) and OwA (2.78%), respectively. Male children were more likely than female children to experience co-occurrence of StOwA [adjusted odds ratio (AOR) (95% CI): 1.96 (1.49–2.57)], OwA [AOR = 1.51: (95% CI) (1.22, 1.86)], and StOw [AOR = 1.59: (95% CI) (1.36, 1.87)]. Children from the poorest and poorer households had higher odds of co-occurrence of StOwA, OwA, and StOw compared to those from the richest households. Compared to children born to mothers with normal body mass index, those born to mothers with overweight/obese had 60% and 39% higher risk, whereas those born to mothers who were underweight had 49% and 36% lower risk of StOw and OwA, respectively. The DBM among children poses a significant public health and economic problem in ESA countries. The DDAs approach should be strengthened in the ESA region to address all forms of malnutrition.

Keywords Anemia, Overweight, Stunting, Double burden of malnutrition, Under-five children, Sub-saharan Africa

Abbreviations

AOR	Adjusted odds ratio
BMIZ	BMI for-age Z score
CI	Confidence interval
DBM	Double burden malnutrition
DDA	Double duty action

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DDS	Dietary diversity score
DHS	Demographic and health surveys
ESA	Eastern and Southern Africa
HAZ	Height for-age Z score
OwA	Overweight and anemia
StOw	Stunting and overweight
StOwA	Stunting overweight and anemia

Malnutrition contributes to nearly half of all deaths among children under-five and significantly hinders their development[1,2]. Globally, over 150 million children are stunted, and more than 380 million children and adolescents are overweight or obese[3,4]. The Eastern and southern African (ESA) regions have the highest prevalence of stunting in the world, with 34.5% and 29%, respectively[5]. Despite significant progress in addressing undernutrition over the past two decades, Africa is the only continent that witnessed increases in the absolute number of stunted and overweight/obese children[5,6].

Early childhood is a critical period for physical and cognitive development and overlooking the dynamic nutritional needs during this period can have serious consequences. Children who experience stunting due to poor nutrition in-utero and early childhood may not attain their full physical and cognitive potentials, resulting in limited productivity and reduced income later in life[7–9]. Additionally, childhood stunting is a risk factor for the developing overweight and diet-related non-communicable diseases later in life[10]. Rapid economic development and urbanization[11,12] have been linked to a shift from traditional diets to diets that are more energy-dense, nutrient-poor foods, and sedentary lifestyles, a phenomenon known as "nutrition transition". This transition fuels the overweight/obesity epidemic, which in turn leads to a higher risk of chronic diseases, including diseases such as diabetes, dyslipidemia, cancers, and mental health disorders[13–15].

In the past, undernutrition and overweight were considered as mutually exclusive public health challenge, each with distinct risk factors[16]. Undernutrition was thought to be associated with poverty, food insecurity, and infections, while obesity was linked to sedentary lifestyles, excess food intake, and higher wealth[17]. However, the double burden of malnutrition (DBM), defined as co-existence of both under nutrition (micronutrient deficiency, underweight, stunting and wasting), and overweight, obesity or diet-related non-communicable disease, has emerged as a major public health issue[16,18]. The recent *LANCET* series highlight the challenges this phenomenon poses in tackling malnutrition effectively[8,18–20].

In low and middle-income countries, these emerging issues of undernutrition and overweight often overlap within individuals, families, households, and communities[21,22] posing significant challenges. These countries are still grappling with the unfinished agenda of under nutrition[23]. A recent study revealed that more than one third of low- and middle-income countries experience overlapping forms of malnutrition, with the Sub-Saharan African bearing the greatest burden[19]. The co-occurrence of DBM at the individual level may result from a combination of poor diet quality and chronic inflammation. Overweight individuals might consume energy-dense but nutrient-poor foods, leading to micronutrient deficiencies like iron deficiency, which causes anemia. Obesity, often associated with chronic inflammation, can impair iron metabolism, further contributing to anemia. Besides, poor nutrition and infections can affect growth, resulting in stunting[20]. Despite these issues, public health policies have primarily focused on tackling undernutrition, paying little attention to the rise of overweight and obesity among children[19].

Recent studies have highlighted that households in sub-Saharan Africa are affected by co-occurrence of overweight/obesity and undernutrition at both the household[24] and country levels[25]. While one study assessed the DBM at individual level, it did not evaluate the risk factors[26]. There is limited evidence on the prevalence and drivers co-occurrence of overweight/obesity and undernutrition at individual level, especially in low-income settings. Furthermore, anemia data has often been excluded from comprehensive analysis of DBM[18] and most studies have focused on individual countries in Africa[27–32]. Therefore, this multi-country study aimed to examine the magnitude of DBM and identify individual and household-level factors affecting co-occurrence of stunting and overweight; overweight and anemia; stunting, overweight, and anemia among under five children in 12 ESA countries.

Methods and materials

Data sources and eligibility criteria

We pooled data of 79,394 children aged 6–59 months from 12 ESA countries' Demographic and Health Surveys (DHSs) in the year 2013–2016. We used the most recent DHS data that was available during the analysis from each of the country during this period. The countries included in our analysis include Angola, Burundi, Democratic republic Congo, Ethiopia, Kenya, Malawi, Namibia, Rwanda, South Africa, Tanzania, Uganda, and Zambia. These twelve countries were purposely selected based on World Bank country classifications by income level with different levels of gross national income (GNI) as a socio-economic development indicator (low income: Malawi; Burundi, Democratic Republic of Congo, Rwanda, Ethiopia, Uganda, Zambia); (lower-middle-income: Angola, Kenya, and Tanzania); upper-middle-income: Namibia, South Africa)[33]. We focused on blocks of ESA region with the aim to influence regional and country level nutrition policies. The DHS collects data on indicators that help to determine child nutritional problems and their determinants. The DHS employs a multistage stratified sampling technique, with households drawn randomly at the final stage. Details of the survey objectives, design, sampling technique, variables assessed, and other information can be accessed in the demographic and health survey official website (https://dhsprogram.com).

Measurements

Outcome

Stunting was defined as Height-for-age Z score (HAZ -score) less than − 2 below the median of the reference population. Overweight and/or obese was defined as Body mass index Z-score (BMIZ) ≥ 2 from the median of the reference population[34]. Anemia was determined based on hemoglobin concentration in blood adjusted to the altitude. In this study, children with hemoglobin level below 11.0 g/dl were considered anemic.

A child is classified as concurrently stunted, overweight, and anemic (StOwA) if the BMI Z-score is greater than 2, HAZ score is less than − 2 and hemoglobin concentration is below 11.0 g/dl. Similarly, a child is classified as concurrently stunted and overweight (StOw) if HAZ score is less than − 2 and BMI Z-score is greater than 2 SD. If BMI Z-score is greater than 2 SD and hemoglobin concentration is below 11.0 g/dl, the child was classified as having concurrent overweight and anemia (OwA). HAZ and BMI Z-score were calculated using the World Health Organization (WHO) Child Growth Standards released on April 27, 2006.

Covariates

We selected covariates a *priori*. Following best practices, we identified these covariates based on the available literature, rather than relying solely on statistical criteria[35,36]. Covariates identified in the literature as being linked to both undernutrition and overweight were included. The following variables were considered; age of the child, sex of the child, maternal educational status, place of residence (urban and rural), wealth index (classified into quintile), Dietary Diversity Score (DDS), maternal BMI (classified as underweight if BMI < 18.5 kg/m^2, normal weight if BMI 18.5–24.9 kg/m^2 and overweight/obese if BMI ≥ 25 kg/m^2), maternal stature, antenatal care follow up, place of delivery, cough in the last two weeks preceding the survey, diarrhea in the last two weeks preceding the survey, birth interval, perceived birth size, access to toilet facility, and drinking water source.

Wealth index is a composite measure of a household's cumulative living standard. It is calculated using household's ownership of certain assets, such as televisions and bicycles; materials used to construct the house: and type of water access and sanitation facilities. The index is generated using principal component analysis. The wealth index places individual households on a continuous scale of relative wealth. Finally, the index is used to classify interviewed households into five quintiles. Each of the households studied were assigned the respective quintiles by DHS[37].

Perceived birth size was assessed by asking the mothers to retrospectively classify their babies' sizes at birth as 'very large', 'larger than average', 'average', 'smaller than average' or 'very small'. For this analysis, we recoded perceived birth size into three categories: large which included 'very large' and 'larger'; 'smaller than average' or 'very small' were categorized as small; and 'average' responses were treated as it was. Birth interval was categorized as optimal, if the pregnancy interval between the indexed child and the immediate older child was ≥ 33 months, otherwise or short[38]. Cough and diarrhea in the last two weeks were assessed to determine presence of recent infection during the survey. It was assessed by asking mothers or caregivers if the index child had cough and/or diarrhea in the last two weeks preceding the survey.

Toilet facility was categorized as improved and unimproved. Improved toilet included flush toilet, piper sewer system, septic tank, ventilated improved pit latrine, pit latrine with slab, and composite toilet[39]. Sources of drinking water were categorized as improved and unimproved. Improved water sources included piped water, public taps, standpipes, tube wells, boreholes, protected dug wells and springs, and rainwater[39].

The DHS uses qualitative 24 h recall of food groups to assess dietary consumption. In this study dietary diversity was measured by minimum DDS. Consumption of at least four varieties of food groups out of the seven items in the past 24 h preceding the survey were considered adequate intake or inadequate if otherwise. The seven-food groups used to estimate DDS were (1) grains and tubers, (2) eggs, (3) flesh foods (meat, fish, poultry, and organ meats), (4) vitamin A rich fruits and vegetables, (5) other fruits and vegetables, (6) legumes, and (7) diary. Consumption of animal source food was treated as independent covariate separately in addition to being included in the DDS.

Statistical analysis

Descriptive statistics were used to describe the socio-demographic characteristics of the study participants. We use Pearson X^2 test to examine if the magnitude of DBM varied by participant characteristics. Since DHS uses a multi-stage cluster sampling design, we used sample weights in all analyses. We used the weighting variable (v005) which was calculated by DHS. We employed '*svy*' command and sample weight (v005/1,000,000) were used to correct for over and under-sampling to improve generalizability of our finding. We tested multicollinearity among independent variables using correlation matrix and Variance Inflation Factors (VIF). Correlation coefficient ≥ 0.85 and VIF > 10 was considered to confirm presence of multicollinearity[40]. Maternal stature, place of birth and ANC follow up were strongly correlated with maternal BMI, maternal education, and birth interval, respectively and therefore excluded from the model. Random effect logistic regression model was used to determine the associations between outcomes and their drivers. Random effect model was selected to account for variability in the data that arises from differences across countries and allow for more accurate estimates. Country was considered as a random variable for the random effect model. We used Husman test to compare whether random or fixed effect model better predict the outcomes. All tests were two-sided, and p-value < 0.05 was considered statistically significant. We presented the main findings using complete-case analyses. SAS version 9 and Stata version 17 were used to analyze the data.

Ethical considerations

The purpose of the analysis was communicated to MEASURE DHS and approval was sought and obtained. The data were downloaded from the official website of the DHS Program (https://dhsprogram.com). The DHS has ethical clearance to conduct the surveys and follows international ethical standards and national ethical guidelines of each country.

Results

The analysis of this study is based on a total sample of 79,394 children aged between 6 and 59 months. Kenya, Zambia, and Ethiopia contributed for about 44.28% of the total sample. A little less than one third (28.86%) of the participants resided in urban areas. Kenya, Zambia, and Angola accounted nearly 52% of the urban sample (Number of participants by country is presented in Table S1).

Table 1 depicted the magnitude of the DBM based on demographic, health and diet related characteristics. Male children were more likely to affected by co-occurrence of StOwA, StOw, and OwA compared to female children. Children from rural residence were more likely to have co-occurrence of StOwA and StO. The co-occurrence of the DBM were also different by maternal education status. Children from mothers with lower educational status (no to primary education) were more likely to be affected by the DBM. Similarly, wealth index, maternal BMI, access to improved drinking water source and other covariates were associated with co-occurrence of StOwA, StO, and OwA. Socio-demographic characteristics of study participants in ESA Africa countries are presented in Table S2.

Dietary consumption

In this study, only one in ten children consumed eggs 24 h preceding the survey. Vitamin A rich fruits and vegetables were consumed by around 19% and animal source foods were consumed by nearly 30% of the survey participants. About two-third of the survey participants consumed grains and tubers. Majority of the study participants (66.60%) had inadequate DDS (Table 2).

Magnitude of double burden of malnutrition

The overall prevalence of stunting, overweight, and anemia was 38.33% (95% CI: 37.98–38.68), 4.71% (95% CI: 4.56–4.87), and 57.97% (95% CI: 57.53–58.41), respectively (Table S3). About 5.38% (95% CI: 5.00-5.79) of children had co-occurrence of StOwA. The prevalence of co-occurrence of OwA and StOw were 5.72% (95% CI: 5.40–6.04) and 4.04% (95% CI: 3.86–4.23), respectively. The highest prevalence of co-occurrence of StOwA was 15.58% (95% CI: 10.62–22.26) in South Africa and the lowest was 2.19% (95% CI: 1.26–3.76) in Namibia. Similarly, South Africa has the highest prevalence of co-occurrence of OwA which was 22.30% (95% CI: 17.01–28.66) whereas the lowest was 2.78% (95% CI: 2.13–3.62) in Burundi. Rwanda has the highest prevalence of co-occurrence of StOw 8.27% (95% CI: 7.07–9.64) while Kenya and Namibia have the lowest prevalence (Fig. 1). Supporting additional information is available in Table S4-S5.

Drivers of double burden of malnutrition

Stunting, overweight, and anemia

Table 3 shows the determinants of co-occurrence of stunting, overweight and anemia. Age, sex of the child, wealth index, and having access to toilet facility were significantly associated with co-occurrence of StOwA. Children aged 48–59 months were 61% less likely [AOR (95%CI): 0.39 (0.23, 0.65)] to have co-occurrence of StOwA than those aged less than 12 months. Male children were 96% more likely [AOR (95%CI): 1.96 (1.49, 2.57)] to have co-occurrence StOwA compared with female children. Household wealth was another driver for the co-occurrence of StOwA. Those from the poorest and poorer households were nearly four times [AOR (95%CI): 3.56 (1.88, 6.73)] and [AOR (95%CI): 3.50 (1.86, 6.60)] more likely to be affected by co-occurrence StOwA than the richest. Having access to improved toilet facility decreased odds of co-occurrence StOwA by 35% [AOR (95%CI): 0.65 (0.47, 0.88)].

Overweight and anemia

As depicted in Table 3, age and sex of the child, household wealth index, maternal BMI, perceived birth size and toilet facility were factors associated with the co-occurrence of OwA. Compared to children aged $<$ 12 months, those aged 12–23, 24–35, 36–47, and 48–59 were 30%, 52%, 60%, and 84% less likely to be affected by co-occurrence of OwA, respectively. Male children were 51% [AOR (95%CI): 1.51 (1.22, 1.86)] more likely to be affected by co-occurrence of OwA. Maternal BMI of ≥ 25 kg/m^2 was associated with 60% increased odds of co-occurrence of OwA 60% [AOR (95%CI): 1.60 (1.24, 2.07)] whereas maternal BMI < 18.5 kg/m^2 was associated with 49% lower odds of co-occurrence of OwA [AOR (95%CI): 0.51 (0.33, 0.80)] Household wealth index and access to improved toilet facility was also associated with OwA.

Stunting and overweight

Compared to children less than 12 months, those aged 12–23, 24–35 and 36–48 months were 70% [AOR (95%CI): 1.70 (1.36, 2.12)], 72% [AOR (95%CI): 1.72 (1.26, 2.35)], and 41% [AOR (95%CI): 1.41 (1.07, 1.84)] more likely to have co-occurrence of StOw while those aged 48–59 months were 32% less likely [AOR (95%CI): 0.68 (0.49, 0.94)] to have co-occurrence of StOw. Male children had 59% higher odds of co-occurrence of StOw than females [AOR (95%CI): 1.59 (1.36, 1.87)]. Children from poorest, poorer, and middle wealth quintiles were 69%, 48%, and 55% more likely to be affected by co-occurrence of StOw than those from the richest households. Compared to children from mother with normal BMI range (18.5–24.9 kg/m^2), children whose maternal BMI < 18.5 kg/m^2 (under-weight) had 36% lower odds co-occurrence of StOw [AOR (95%CI): 0.64 (0.47, 0.88)] whereas children whose maternal BMI ≥ 25 kg/m^2 (overweight and obese) had 39% higher odds of co-occurrence of StOw [AOR (95%CI): 1.39 (1.14, 1.70)]. Having access to improved toilet facility were found to decrease odds of StOw.

Variables	Category	Co-occurrence of StOwA			Co-occurrence of StOw			Co-occurrence of OwA		
		Total (n)	StAOw (n)	P-value	Total (n)	StOw (n)	P-value	Total (n)	OwA (n)	P-value
Age	< 12 months	1,237	82	< 0.001	7,518	205	< 0.001	1,570	179	< 0.005
	12–23 months	2,311	180		10,174	493		3,803	343	
	24–35 months	3,096	192		9,989	511		5,091	302	
	36–48 months	3,519	149		10,374	385		5,610	215	
	48–59 months	4,182	60		10,899	173		6,045	93	
Child sex	Male	6,883	401	< 0.001	24,229	1,061	< 0.001	10,914	655	< 0.001
	Female	7,687	279		25,986	753		11,518	513	
Maternal education	No education	3,073	193	< 0.001	10,874	392	< 0.001	5,449	282	0.015
	Primary education	6,550	357		23,702	997		10,412	586	
	Secondary education	4,344	126		13,390	392		5,888	275	
	Higher	603	4		2,246	32		683	25	
Place of residence	Urban	4,634	150	< 0.001	16,222	481	< 0.001	6,282	322	0.733
	Rural	9,936	530		33,993	1,333		16,150	846	
Wealth index in quantiles	Poorest	2,888	197	< 0.001	12,345	500	< 0.001	4,906	286	< 0.001
	Poorer	2,792	180		10,101	426		4,644	271	
	Medium	2,670	152		9,524	406		4,383	248	
	Richer	2,941	88		9,143	280		4,319	187	
	Richest	3,279	63		9,102	202		4,180	176	
Maternal BMI	18.5–24.9 kg/m^2	8,436	416	0.001	26,539	1,097	< 0.001	13,503	662	< 0.001
	< 18.5 kg/m^2	1,160	34		4,023	86		1,997	47	
	≥ 25 kg/m^2	3,607	138		9,923	399		4,822	302	
ANC follow up	≥ 4 visits	3,887	240	< 0.001	15,123	649	< 0.001	6,346	400	0.068
	≤ 3 visits	5,496	213		19,848	636		7,906	441	
Cough in the last two weeks	No	10,804	532	0.016	14,759	424	< 0.001	16,510	888	0.053
	Yes	3,738	148		35,759	1,388		5,883	278	
Diarrhea in the last two weeks	No	12,610	564	0.003	8,042	306	0.319	19,252	965	0.001
	Yes	1,928	116		42,082	1,506		3,135	201	
Perceived birth size	Large	5,107	258	0.067	14,333	633	< 0.001	7,454	478	< 0.001
	Average	7,512	340		23,591	873		11,454	556	
	Small	1,788	67		5,618	181		3,248	109	
Birth interval	Short	2,061	124	0.004	6,825	275	0.066	3,336	181	0.276
	Optimal	9,216	416		32,070	1,145		14,134	702	
Toilet facility	Improved	6,806	264	0.001	21,366	716	0.046	9,869	510	0.621
	Unimproved	6,348	324		25,203	931		10,310	517	
Deworming	Yes	6,242	293	0.314	21,809	734	< 0.001	10,463	531	0.656
	No	6,929	300		18,607	855		9.821	485	
Drinking water source	Improved	9,808	383	< 0.001	31,880	1,035	< 0.001	14,745	719	0.009
	Unimproved	4,454	276		17,043	731		7,237	413	
Animal source food consumption	Yes	2,301	146	0.327	8,290	767	0.954	8,548	538	0.001
	No	5,358	309		18,524	342		3,363	267	
DDS	Inadequate	4,842	310	0.027	17,601	759	0.045	7,623	505	0.417
	Adequate	2,809	145		9,164	348		4,277	300	

Table 1. Burden of double burden of malnutrition by sociodemographic, health and diet related characteristics in Eastern and Southern African countries. BMI; body mass index, DDS; diet diversity score, StOwA; stunting overweight and anemia, StOw; stunting and overweight, OwA; overweight and anemia.

Discussion

This multi-country study aimed to determine the magnitude of DBM among under five children and identify household and individual level drivers in 12 ESA countries. The study revealed a high burden of co-occurrence of StOwA, StOw, and OwA among under-five children. The highest co-occurrence of StOwA and OwA was observed in South Africa, while the lowest StOwA was in Namibia and the lowest OwA was in Burundi. Male children were more likely to experience StOwA, StOw, and OwA compared to their female counterparts. Children from poorer households were more likely to be affected by co-occurrence of stunting, overweight and anemia than those from richer households. Access to improved toilet facilities was associated with decreased odds of co-occurrence of stunting, overweight and anemia. Additionally, higher maternal BMI (≥ 25 kg/m2) was

Variable	Category	Frequency	Percentage
Grains and tubers (n = 42,683)	Yes	26,768	62.71
	No	15,915	37.29
Egg (n = 42,656)	Yes	4,629	10.85
	No	38,027	89.15
Flesh food (Meat) (n = 42,642)	Yes	8,411	19.72
	No	34,231	80.28
Vitamin-A rich fruits and Vegetables (n = 42,668)	Yes	8,062	18.89
	No	34,606	81.11
Other fruits and vegetables (n = 42,661)	Yes	7,550	17.70
	No	35,111	82.30
Legumes (n = 44,990)	Yes	10,030	23.51
	No	32,625	76.49
Diary (n = 42,671)	Yes	1,963	4.60
	No	40,708	95.40
Dietary diversity score (n = 44,900)	Inadequate	28,350	66.60
	Adequate	14,220	33.40
Animal source food consumption (n = 44,972)	Yes	12,461	29.23
	No	30,177	70.77

Table 2. Type of diet consumption among children in in Eastern and Southern African countries.

associated with increased odds of StOw and OwA in children compared to those born to mothers with normal BMI.

More than one-third of the children (37%) were stunted, which is higher than the average prevalence of stunting (29%) for Africa reported by the WHO, United Nations Children's Fund (UNICEF), and the World Bank in their 2019 joint child malnutrition estimates[5]. In 2013, the estimated prevalence of stunting in Africa and Asia was 36% and 27%, respectively[6]. The difference in our estimate could be that out estimate was from only 12 countries, whereas the WHO and UNICEF report included data from all African nations. The persistently high prevalence of stunting indicates that Africa is still lagging behind in meeting the target to reduce childhood stunting. On the other hand, the prevalence of overweight in the present study was lower than the projected prevalence for Eastern Africa (8.7%) and Southern Africa (6.5%) by De Onis et al.[41].

About 5% of under five children in our study experienced the co-occurrence of StOwA with a similar magnitude of co-occurrence of OwA and StOw. The co-occurrence of this multiple forms of malnutrition is due to common underlying factors contributing to both overweight and linear growth faltering or micronutrient deficiency, as suggested by previous studies on etiologic pathways[20,42]. Disadvantaged socioeconomic status was not only associated with the risk of undernutrition but also with increased odds of overweight/obesity. Children from household with low to moderate wealth, mothers with a high BMI, and those without access to improved toilet facilities had higher odds of experiencing both overweight/obesity and undernutrition simultaneously. This underscores the need to shift the focus of interventions from predominantly addressing undernutrition to tackling all forms of malnutrition in low- and middle-income countries.

Among the 12 countries in this study, South Africa, an "upper middle-income country" with the highest GDP per-capita, had the highest prevalence of co-occurrence of StOwA, and co-occurrence of OwA. Conversely, Namibia and Burundi had the lowest prevalence of this conditions, respectively. This finding supports the notion that while economic growth significantly contributes to increased rates of overweight individuals, it does not necessarily alleviate undernutrition to the same extent. As a result, countries with a high GDP per capita could face a dual challenge related to malnutrition[43]. Previous studies have also noted the link between economic development and urbanization with an increased prevalence of overweight in children[14,44,45].

Male children were about twice more likely to experience co-occurrence of StOwA compared to female children. Similarly, male children had higher odds of experiencing co-occurrence of StOw and OwA. Consistent with our findings, Gubert et al. found that DBM was prevalent among households with male child in Brazil[46]. A study among under-five children in 10 sub-Saharan African countries also indicated that male children are more likely to be stunted compared to their female counterparts[47], increasing the likelihood of DBM. The undernutrition of boys might be due to the preferential treatment of girls over boys due to social factors in developing countries[48,49] and the increased vulnerability of males to morbidity in early infancy[50].

The wealth index, which plays a central role in the distribution of under- and overweight/obesity, was another significant factor associated with the co-occurrence of malnutrition in our study. Children with households in the poorer and poorest wealth quintiles were more likely to experience the co-occurrence of stunting, overweight and anemia compared to those from the richest households. Other studies have also reported that economic inequality is a major deriver of the DBM, with the inequality consistently being pro-poor socio-economic in sub-Saharan Africa[24,26,43,51].

Although maternal BMI was not significantly associated with co-occurrence of StOwA, consistent with other studies[27,52], we found an increased risk of co-occurrence of StOw and OwA among children born to overweight/

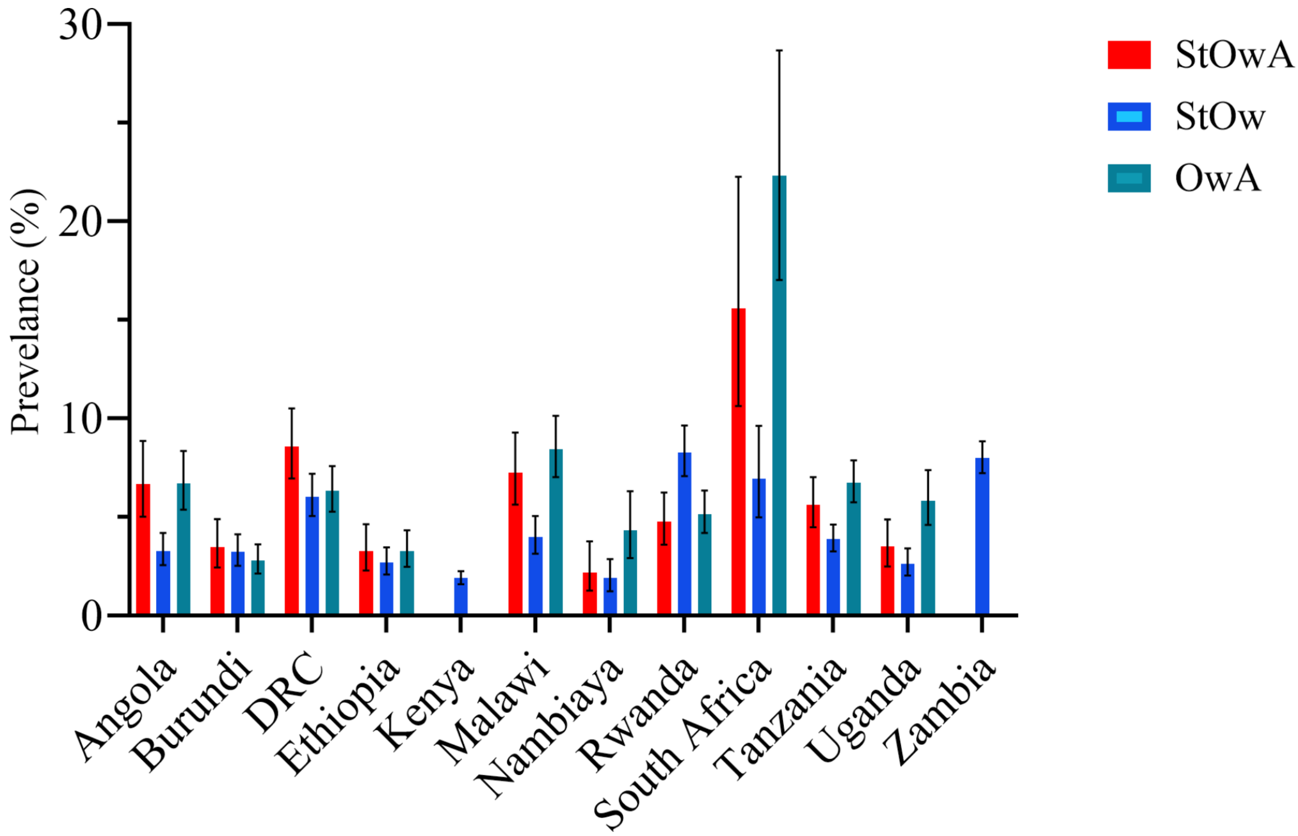

Fig. 1. Co-occurrence of undernutrition and overnutrition at individual level in 12 Eastern and Southern African countries. StOw; stunting and overweight, OwA; overweight and anemia, StOwA; stunting overweight and anemia. Kenya and Zambia did not have anemia data.

obese mothers. Other studies have shown that parental BMI is a significant determinant of childhood overweight[53,54]. While genetic factors may influence total body fat, the shared environment is more likely to explain the association between maternal and childhood overweight[55]. One potential biological explanation could be that pregnant women with overweight or obesity exhibit low-grade inflammation, which may result in suboptimal growth of their offspring[56,57].

Unsurprisingly, households with improved toilet facilities had a reduced risk of co-occurrence of malnutrition in this study. This finding aligns with previous research that assessed the determinants of DBM at household level[24]. Improved toilet facility reduce the risk of infections, which in turn lowers the risk of anemia and growth faltering[58]. Additionally, households with improved toilet facilities are more likely to belong to higher income categories and tend to have better sanitation and hygiene, greater utilization of health services, and higher rates of exclusive breast feeding[59,60]. This factors collectively contribute to a reduced risk of anemia and growth faltering.

The present study provided important evidence on the DBM in ESA countries. Our study should be interpreted in the context of the following limitations. First, as an observational study, it does not allow causal inferences, and there is possibility of reverse causation. Hence, high-quality studies such as prospective longitudinal studies are warranted to confirm causation and address potential reverse causation. Second, data on presence of cough in the last two weeks, deworming tablet use in the past six months, and diet consumption are based on reports by mothers which may be affected by recall bias. This bias could have led to either overestimation or underestimation of the effect sizes reported in this study. Third, community-level determinants of malnutrition also play a significant role in the burden of DBM. However, due to data constraints, we were unable to assess these factors in our study. Future research should investigate these community-level determinants. Notwithstanding these, the use of multi-country data that adjusted for various covariates is a key strength of the study.

Conclusion

This study underscores the critical challenge posed by the DBM among children under five years of age in ESA countries. Age and sex of the child, wealth index, maternal BMI, access to improved toilet facility cough in the last two weeks before the survey and perceived birth size had a significant association with co-occurrence of overweight with stunting and/or anemia. The co-occurrence of stunting, overweight, and anemia calls for policies and programs to address the challenge of DBM through an integrated maternal and child health program by focusing on the identified factors. The finding of this study underscores the need to prioritize double duty interventions that can simultaneously tackle multiple forms of malnutrition.

Variables	Category	StOwA			StOw			OwA		
		AOR	Lower CI	Upper CI	AOR	Lower CI	Upper CI	AOR	Lower CI	Upper CI
Age	< 12 months	Ref			Ref			Ref		
	12–23 months	1.06	0.72	1.56	**1.70**	**1.36**	**2.12**	**0.70**	**0.53**	**0.92**
	24–35 months	0.92	0.54	1.56	**1.72**	**1.26**	**2.35**	**0.48**	**0.32**	**0.72**
	36–47 months	0.93	0.60	1.44	**1.41**	**1.07**	**1.84**	**0.40**	**0.28**	**0.57**
	48–59 months	**0.39**	**0.23**	**0.65**	**0.68**	**0.49**	**0.94**	**0.16**	**0.11**	**0.25**
Child sex	Female	Ref			Ref			Ref		
	Male	**1.96**	**1.49**	**2.57**	**1.59**	**1.36**	**1.87**	**1.51**	**1.22**	**1.86**
Maternal education	No education	1.58	0.44	5.73	0.95	0.52	1.73	1.69	0.66	4.27
	Primary education	1.47	0.42	5.15	0.98	0.55	1.75	1.75	0.71	4.30
	Secondary education	0.95	0.27	3.32	0.79	0.45	1.41	1.40	0.57	3.44
	Higher	Ref			Ref			Ref		
Place of residence	Urban	Ref			Ref			Ref		
	Rural	0.94	0.61	1.43	1.23	0.97	1.55	0.88	0.64	1.21
Wealth index	Poorest	**3.56**	**1.88**	**6.73**	**1.69**	**1.15**	**2.48**	**1.77**	**1.12**	**2.81**
	Poorer	**3.50**	**1.86**	**6.60**	**1.48**	**1.02**	**2.16**	**1.83**	**1.16**	**2.89**
	Medium	**2.56**	**1.37**	**4.77**	**1.55**	**1.09**	**2.20**	1.39	0.88	2.17
	Richer	**1.85**	**1.03**	**3.33**	1.24	0.88	1.74	1.45	0.97	2.17
	Richest	Ref			Ref			Ref		
Maternal BMI	18.5–24.9 kg/m^2	Ref			Ref			Ref		
	< 18.5 kg/m^2	0.63	0.37	1.06	**0.64**	**0.47**	**0.88**	**0.51**	**0.33**	**0.80**
	≥ 25 kg/m^2	1.33	0.94	1.88	**1.39**	**1.14**	**1.70**	**1.60**	**1.24**	**2.07**
Cough in the last two weeks	Yes	0.72	0.52	1.00	**0.70**	**0.58**	**0.86**	0.87	0.68	1.11
	No	Ref			Ref			Ref		
Diarrhea in the last two weeks	Yes	0.92	0.63	1.35	0.87	0.70	1.08	0.91	0.69	1.19
	No	Ref			Ref			Ref		
Perceived birth size	Large	Ref			Ref			Ref		
	Average	1.23	0.91	1.66	0.96	0.81	1.14	**0.74**	**0.59**	**0.93**
	Small	0.95	0.60	1.52	0.91	0.69	1.20	**0.63**	**0.44**	**0.91**
Birth interval	Short	0.94	0.67	1.31	0.92	0.75	1.13	1.05	0.80	1.36
	Optimal	Ref			Ref			Ref		
Toilet facility	Improved	Ref			Ref			Ref		
	Unimproved	**0.65**	**0.47**	**0.88**	**0.76**	**0.64**	**0.92**	**0.71**	**0.56**	**0.91**
Deworming	Yes	Ref			Ref			Ref		
	No	1.05	0.78	1.41	0.98	0.82	1.16	1.05	0.83	1.31
Drinking water source	Improved	Ref			Ref			Ref		
	Unimproved	0.83	0.59	1.16	1.03	0.86	1.24	1.01	0.79	1.31
Dietary diversity score	In adequate	0.76	0.54	1.06	0.87	0.71	1.07	0.80	0.62	1.04
	Adequate	Ref			Ref			Ref		
Animal source food consumption	Yes	0.99	0.70	1.41	1.06	0.86	1.30	0.95	0.72	1.25
	No	Ref			Ref			Ref		

Table 3. Factors associated with double burden of malnutrition in in Eastern and Southern African countries. Analyses results are based on complete case analyses. AOR; adjusted odd ration, BMI; body mass index, CI; confidence interval, StOwA; stunting overweight and anemia, StOw; stunting and overweight, OwA; overweight and anemia. Bold indicate significant values at $p < 0.05$.

Data availability
The data used in the current paper are available from DHS program. The analytic code will be made available upon reasonable request from the corresponding author.

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Author contributions
B.G. Conceived the idea, designed the research, data management and analysis, and wrote the main manuscript and had primary responsibility for final content. A.A. Contributed to designing the study, wrote the manuscript, and participated in the critical revision of the manuscript. S.B., K.B. and S.J.Z. contributed to the design of the research and critically reviewed the report. D.H. Conceived the idea, designed the research, data management and analysis, and critically reviewed the manuscript. All authors read and approved the final manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Ethical approval
The data were downloaded from the official website of the DHS Program (https://dhsprogram.com/) after the purpose of the analysis was communicated and approved by MEASURE DHS. The original DHS data were collected in conformation with international ethical standards and national ethical guidelines of each country.

Additional information
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