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Socio-demographic and environmental risk factors accounting for the co-existence of wasting, stunting, and underweight in children under five: Analysis of cross-sectional surveys from 31 sub-Saharan African countries

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ABSTRACT

Objective: This study investigated the socio-demographic and environmental risk factors of the co-existence of wasting, stunting, and underweight among children under age five in sub-Saharan Africa.

Methods: Data from 31 sub-Saharan African countries were pooled from the Demographic and Health Surveys (DHS) collected between 2010 and 2019. We examined the risk of co-existence of malnutrition using multinomial logistic regression models, withresults presented as relative risk ratios (RRR) with their respective confidence intervals.

Outcome meaures: The outcome variables were three child anthropometrics: stunting (height-for-age z-scores); wasting (weight-for-height z-scores); and underweight (weight-for-age z-scores).

Results: The prevalence of co-existence of stunting, wasting and underweight varied across countries and sub-regions, with the highest and lowest prevalence of co-existence of stunting, wasting, and underweight as Benin (12.14%) and Gambia (0.58%) respectively. The risk of co-existence of the three malnutrition dimensions was higher among children age 1 year compared to those aged 0. Children who were females were less likely to have a co-existence of the three dimensions of malnutrition compared to their male counterparts. The risk of co-existence of the three dimensions was higher among children with small size at birth, those whose mothers had no education, not working, had no antenatal visits during pregnancy, children delivered at home, those whose mothers were poor, had no access to media, and children whose mothers had unimproved toilet facility.

Conclusion: Findings suggest context nutrition-specific interventions such as complimentary feeding, dietary supplementation and increasing dietary diversity to promote children feeding practices in the studied countries are warranted. Planned interventions should prioritize all the identified factors noted in the current study to help reduce the risks of co-existence of stunting, wasting, and underweight among children under age 5.

Keywords: co-existence; wasting; stunting; underweight; children under five; sub-Saharan Africa

Strength and Limitations

- The use of nationally representative data ensures that our findings are generalizable and replicable in the 31 SSA countries included in this study.
- Findings contribute to bridging the gaps identified in the current research on CNS by including multiple indicators (stunting, wasting, and underweight) in the concurrent measurement of our outcome variable, compared to the unitary assessment on malnutrition that currently dominates literature.
- The study relied on secondary data, the analysis was limited to only variables that were in the dataset. Hence, interpretations and inferences made from current findings must be limited to only these observed variables.
- Also, the DHS employs cross-sectional designs which restrict causality on the noted outcomes.
- The key variables were self-reported by the mothers, and therefore, there is the likelihood of recall bias and other social desirability concerns in the present study.

BACKGROUND

Malnutrition among children under 5 years remains a major public health problem across many developing countries[1-3] . Factors such as insufficient food intake, diarrhoea, recurring infections, poor sanitation practices, and low parental education have been identified as significant contributors to the high prevalence of malnutrition during childhood[1,4,5] . Despite the numerous interventions rolled out to address childhood malnutrition especially in sub-Saharan Africa where the phenomenon is quite pervasive, the progress seems to be insignificant[6,7]. For example, a study reported that child malnutrition accounted for nearly half (45%) of child mortality rate in developing countries[8]. Aside from that, it was reported in 2018 that about 149 million and 49 million children under age 5 were stunted and wasted respectively[9].

Three main indicators that are often used to represent malnutrition are underweight or low weight for age, stunting or low height for age, and wasting or low weight for height[2,10-12] . Among the three indicators of malnutrition, stunting has been identified as the problem with the greatest magnitude among under 5 children in developing countries[2,3] . Even though the prevalence of stunting in sub-Saharan Africa is declining, it is worth noting that it is still above 30%[13] which is undeniably high. Research also indicates that the country-specific prevalence of wasting, underweight, and stunting is still high[2,3] . For instance, in Ethiopia, the prevalence of wasting and stunting were 10% and 38% respectively[14] . Additionally, the prevalence of stunting, underweight and wasting among children in South Africa were 35.8%, 20.5%, and 17.2%[3]. Likewise, Anin et al.[2] reported 33.2%, 14.1%, 27% and 2.6% of prevalence in stunting, wasting, underweight and overweight among infants (6-23 months) across Northern Ghana.

Previous studies have investigated the socio-demographic and environmental risk factors associated with wasting, stunting and underweight among children under 5 years and found the age of a child, sex of the child, child's size at birth, mother's age during childbirth, mother's educational level, birth order, place of residence and mother's body mass index (BMI) as associated factors[1-3,15,16] . Other studies also found significant linkage between household wealth quintile and maternal short stature, and nutritional status of children under 5[17,18] . Regarding the sex of child, for example, female children were found to be less likely to suffer from stunting compared to males[1,3] .

Despite the detrimental consequences of malnutrition on the health and wellbeing of children under 5, it appears few studies have utilised current nationally representative data from a larger sample to investigate the socio-demographic and environmental risk factors associated with stunting, underweight and wasting among this age group, making it difficult for policymakers and nutritional experts to provide up-to-date trends with appropriate strategies to curb the situation in the sub-region. This research lag presents a void in extant literature which this study seeks to bridge.

Therefore, the study investigated the socio-demographic and environmental risk factors of the co-existence of wasting, stunting, and underweight among children under age 5 in sub-Saharan Africa using data from the Demographic Health Survey (DHS) conducted in 31 countries between 2010 and 2019. The findings of the study could contribute to the formulation of policies and interventions to respond to the nutritional needs of children

under 5 years and also suggest pragmatic ways of reducing malnutrition among children in the sub-region.

Malnutrition is one of the pervasive and leading causes of death, especially among children. Globally, more than half of child mortally is attributed to malnutrition[19] . In developing countries, especially, in Africa, the prevalence of nutritional insecurity among children is staggering. According to studies[20,21] , SSA accounts for a disproportionate number of children suffering from malnutrition in the world. The situation is more alarming as the co-existence of stunting, wasting and underweight and other diet-related (double burden) is increasingly becoming prevalent[2]. The World Health Organization (WHO) report[22] indicates that aggressive actions are needed to address the double burden of malnutrition to achieve the 6 global nutrition targets by 2025. This call underscores the need for more research that provides useful insights that could inform policy actions and intervention programming. Studies have examined the independent prevalence of stunting, wasting, and underweight and the risk factors associated with each of them among children under the age of 5years in sub-Saharan African countries[21] . However, the "multiple burdens", that is, the co-existence of the three conditions among children under the age of 5years in SSA has received little attention. Here, we analyze the prevalence of the co-existence of stunting, wasting, and underweight among children under the age of 5years and the risk factors associated with it in SSA.

METHODS

Data Source

Data of 127,487 children under the age of 5 years from 31 sub-Saharan African countries were pooled from the most current Demographic and Health Surveys (DHS) conducted between 2010 and 2019 (Table 1). Specifically, the data were pooled from the children's file in each of the countries. The DHS Program has conducted over 400 surveys in over 90 developing countries around the world since 1984 every five years[23] . The program implements cross-sectional surveys to gather nationally-representative data, analyze and disseminate accurate information on important demographic and health indicators spanning population, nutrition, and diseases. For all surveys, standardized protocols designed for each target group including children, women, and men at the household level are employed to allow for cross-national comparisons. Stratified two-stage sampling involving first, the listing of enumeration areas and selection of clusters, and then a random selection of households in each cluster. The detailed sampling method can be found in a previous study[24].The dataset is freely available for download at: https://dhsprogram.com/data/available-datasets.cfm. The Strengthening Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed in writing the manuscript[25] .

Study Variables

Outcome Variable

The outcome variable considered in this study is derived from three child anthropometric variables including stunting (height-for-age z-scores); wasting (weight-for-height z-scores); and underweight (weight-for-age z-scores). The DHS (2021) specifies categorization for each of these variables following the WHO child growth standard. Following this standard, the three variables were first coded as follows:

i. Stunting: children with height-for-age z-scores below minus 2 (-2.0) standard deviations (SD) less than the mean on the WHO Child Growth Standards (moderately or severely stunted) and children with height-for-age z-scores below minus 3 (-3.0) standard deviations (SD) less than the mean on the WHO Child Growth Standards (severely stunted) were combined to form the response group "Stunt" while those height-for-age z-scores higher than minus 2 (-2.0) standard deviations (SD) greater than the mean on the WHO Child Growth Standards were regarded as "normal". These response categories were coded as 0 "Normal" and 1 "Stunt".

ii. Wasting: children with weight-for-height z-scores below minus 2 (-2.0) standard deviations (SD) less than the mean on the WHO Child Growth Standards (moderately or severely wasting) and children with weight-for-height z-scores below minus 3 (-3.0) standard deviations (SD) less than the mean on the WHO Child Growth Standards (severely wasting) were combined to form the response group "Wasting" while those weight-for-height z-scores higher than minus 2 (-2.0) standard deviations (SD) greater than the mean on the WHO Child Growth Standards were regarded as "Normal". These two response categories were coded as 0 "Normal" and 1 "Wasting"

iii. Underweight: children with weight-for-age z-scores below minus 2 (-2.0) standard deviations (SD) less than the mean on the WHO Child Growth Standards (moderately or severely underweight) and children with weight-for-age z-scores below minus 3 (-3.0) standard deviations (SD) less than the mean on the WHO Child Growth Standards (severely underweight) were combined to form the response group "Underweight" while those weight-for-age z-scores higher than minus 2 (-2.0) standard deviations (SD) greater than the mean on the WHO Child Growth Standards were regarded as "Normal". These two response categories were coded as 0 "Normal" and 1 "Underweight". For each of these variables, missing and "flagged" responses were deemed invalid and dropped.

These three variables were then added to generate the outcome variable "Co-existed malnutrition" with scores (discrete) ranging from 0 to 4 where 0 implies "Normal", that is, children with none of the three conditions; 1 implies "Single burden", that is, the child suffers from one of the three conditions; 2 indicates that child suffers from "Two burdens" out of the three; and 3 shows "Co-existed", that is, the child suffers from all three conditions of malnutrition. For parsimony, children who suffered from "Single burden" and those who suffered from "Two burdens" were added resulting in the variable "Co-existed malnutrition" with three response categories: 0=Normal; 1=One or two burdens; and 3=co-existed.

Independent Variables

Several risk factors spanning socio-demographic and environmental have been associated with child malnutrition. The relevant biosocial characteristics and sociocultural factors related to the child, mother, household head and the household together form compositional factors[26,27] . Factors that describe location or "place-based" variables are contextual factors[26,28,20] . In this study, contextual and composition factors except household-level characteristics related to environment and sanitation are categorized as "Socio-demographic risk factors". Socio-cultural household characteristics related to environment and sanitation are categorized as "Environmental risk factors".

Socio-Demographic Risk Factors

The relevant variables under socio-demographic risk factors considered include the age of the child (0, 1, 2 and 4); sex of child (female and male); birth order of child (1, 2 to 4, and 5 and above); perceived size at birth (small, average and large (see[15]); mother's age (re-coded into two categories "15-19" years and "20-49" years); educational attainment (no formal, primary, secondary and higher); working status (yes and no); antenatal visits during pregnancy (yes and no); postnatal check within 2 months (yes and not); and place of delivery (home, health facility, other). At the household level, relevant variables included are the wealth status (recode as "poor", "middle" and "rich"); the age of household head (recode as ages below 35 years "young adults", between 35 and 55 years "middle-aged adults" and those above 55 years "Old-aged adults" (see[28]); sex of household head (male and female); access to electricity (yes and no); and access to media (yes, no) which was derived from the three variables "access to television", "radio" and "newspaper". The contextual factors considered are Urbanicity (rural and urban) and the country of origin of the participant.

Environmental Risk Factors

We considered the following variables: type of toilet facility (re-coded into "improved" and unimproved" (see[28]); source of drinking water (re-coded as "improved" and "unimproved" (see[28]); and type of household cooking fuel (re-coded into "clean" and "unclean" (see28,30) under the category "environmental risk factors"

Data Analyses

The statistical analysis of the data was performed using the Stata SE software version 14.2. The "svyset" command was first used to declare the data as survey data to prevent the potential effects of the complex sampling techniques on the analyses. To understand the distributions of the variables, the data were summarized and presented in tables using descriptive statistics (frequencies, weighted percentages, and 95% confidence intervals (CIs) of percentages). We further integrated the data into a GIS environment and presented the distribution of key variables across the study countries in map images. This approach enhances the visualization of the data and understanding of the context of the study. The associations between the co-existence of malnutrition and each of the risk factors considered were assessed using the chi-square test of independence, with results presented in a contingency table. The risk factors as independent variables were then subjected to collinearity diagnosis tests, including Variance Inflation Factors (VIF), Square VIF, Tolerance, and R-squared. To determine the socio-demographic and environmental

risk factors associated with the co-existence of malnutrition, a multinomial regression model was implemented. The sample weight variable was used to adjust for potential over-and under-sampling. All statistical tests were conducted at $p<0.05$.

Ethical Approval

DHS reports ethical clearance are provided by the Ethics Committee of ORC Macro Inc. as well as Ethics Boards of partner institutions (e.g., Ministries of Health) from studied countries. The DHS procedures require that principles for the protection of respondents' anonymity and confidentiality are adhered. Inner City Fund International also guarantees that the survey protocols meet the United States Department of Health and Human Services' regulations for the respect of human subjects. The current study used a secondary data, hence, no further ethical approval was sought. The datasets are freely available for download and usage at https://dhsprogram.com/data/available-datasets.cfm.

Table 1: Distribution of socio-demographic, environmental and contextual variables

Variable (N=127,487)	n	%	Variable (N=127,487)	n	%
Socio-demographic factors			**Access to media (tv/radio/newspaper)**		
Age of child			Yes	45,043.56	35.33
0	39,353.73	30.87	No	82,443.74	64.67
1	36,230.39	28.42	**Urbanicity**		
2	25,774.66	20.22	Urban	42,343.17	33.21
3	15,811.30	12.4	Rural	85,144.13	66.79
4	10,317.23	8.09	**Country**		
Sex of child			Angola	7,318.29	5.74
Male	64,348.16	50.47	Benin	15,472.88	12.14
Female	63,139.14	49.53	Burkina Faso	8,907.87	6.99
Birth order			Burundi	4,171.93	3.27
1	24,883.00	19.52	Cameroon	2,910.63	2.28
2 to 4	61,308.45	48.09	Chad	5,998.88	4.71
5 and above	41,295.86	32.39	Comoros	1,319.47	1.03
Perceived size at birth			Congo	2,608.83	2.05
Large	42,978.82	33.71	Cote d'Ivoire	2,174.34	1.71
Average	63,409.91	49.74	DR Congo	4,805.87	3.77
Small	21,089.84	16.54	Ethiopia	6,572.69	5.16
Mother's characteristics			Gabon	1,959.93	1.54
Maternal age			Gambia	742.5298479	0.58
15-19	9,092.47	7.13	Ghana	1,896.02	1.49
20-49	118,394.83	92.87	Guinea	2,236.99	1.75
Educational attainment			Kenya	6,065.78	4.76
No education	53,320.68	41.82	Lesotho	1,011.75	0.79
Primary	39,847.27	31.26	Liberia	1,945.96	1.53
Secondary	30,365.61	23.82	Malawi	4,026.75	3.16
Higher	3,953.74	3.1	Mali	5,653.33	4.43

Working status			Namibia	905.1925663	0.71
No	45,209.54	35.49	Nigeria	7,379.03	5.79
Yes	82,175.43	64.51	Rwanda	4,408.42	3.46
Antenatal visits during pregnancy			Senegal	1,943.55	1.52
No	13,710.30	10.76	Sierra Leone	2,689.41	2.11
Yes	113,759.99	89.24	South Africa	854.9645807	0.67
Postnatal check within 2 months			Tanzania	6,060.69	4.75
No	74,571.69	58.49	Togo	2,220.15	1.74
Yes	52,915.61	41.51	Uganda	2,890.85	2.27
Place of delivery			Zambia	6,347.36	4.98
Home	39,934.13	31.33	Zimbabwe	3,986.95	3.13
Health facility	86,065.94	67.51	**Environmental factors**		
Other	1,481.88	1.16	**Type of toilet facility**		
Wealth status			Improved	54,131.64	42.47
Poor	54,066.08	42.41	Unimproved	73,331.75	57.53
Middle	25,855.00	20.28	**Source of drinking water**		
Rich	47,566.22	37.31	Improved	83,659.77	65.63
Age of household head			Unimproved	43,815.68	34.37
Young-adults	54,920.16	43.08	**Type of cooking fuel**		
Middle-aged adults	55,787.81	43.76	Clean	114,424.88	89.76
Old-aged adults	16,778.46	13.16	Unclean	13,049.03	10.24
Sex of household head			Geographic region		
Male	101,698.36	79.77	Western	53,262.07	41.78
Female	25,788.94	20.23	Eastern	41,863.95	32.84
Access to electricity			Central	25,602.42	20.08
No	88,219.82	69.2	South Africa	6,758.86	5.3
Yes	39,257.69	30.8			

Figure 1

Figure 2

Patient and public involvement

Patients and the public were not involved in the design and conduct of this research

Results

Descriptive Analysis on the Prevalence of Co-existence of Stunting, Wasting and Underweight Varied across Countries and Sub-Regions

The prevalence of co-existence of stunting, wasting and underweight varied across countries and sub-regions, with the highest and lowest prevalence of co-existence of stunting, wasting, and underweight as Benin (12.14%) and Gambia (0.58%) respectively

(Figure 1). In terms of sub-region, the highest prevalence of co-existence of stunting, wasting, and underweight was observed in Western Africa (41.78%) and the lowest prevalence in Southern Africa (5.3%) (Figure 2). Significant associations between all the independent variables and co-existence of stunting, wasting, and underweight, except maternal age and age of household head were identified (Table 2).

Multinomial Logistic Regression Results of Risk Factors for Co-existence of One and a Co-Existence of Two Dimensions of Malnutrition

Table 3 shows the results of the multinomial regression analysis of the risk factors of co-existence of dimensions of malnutrition (stunting, wasting, and underweight) among children under five years in the SSA. Children aged 1year [RRR = 2.008, 95% CI = 1.930, 2.089], two years [RRR = 2.624, 95% CI = 2.514, 2.739], three years [RRR = 2.122, 95% CI = 2.018, 2.231], and four years [RRR = 1.504, 95% CI = 1.417, 1.597] were more likely to have one or two dimensions of the malnutrition. The risk of having one or a coexistence of two dimensions of malnutrition was higher among children with average size at birth [RRR = 1.320, 95% CI =1.276, 1.365] and small size at birth [RRR = 1.931, 95% CI =1.846, 2.020] compared to those with large size at birth. Compared to children whose mothers had attained higher educational level, the risk of developing one or a coexistence of two malnutrition dimensions was higher among children whose mothers had no education [RRR = 2.624, 95% CI =2.305, 2.987], primary [RRR = 2.189, 95% CI = 1.927, 2.487], and secondary [RRR = 1.751, 95% CI = 1.545, 1.987] educational attainment respectively. However, this risk decreased with increasing educational attainment. The risk of developing one or a coexistence of two malnutrition dimensions was lower among children who were females [RRR = 0.752, 95% CI = 0.731, 0.775], those with second birth order [RRR = 0.938, 95% CI =0.896, 0.981], those whose mothers were aged 20-49 years [RRR = 0.834, 95% CI = 0.780, 0.891], those whose age of household head was middle-aged [RRR = 0.954, 95% CI = 0.921, 0.987], and those whose source of drinking was unimproved [RRR = 0.959 , 95% CI = 0.928, 0.990].

Also, children whose mothers did not visit the antenatal clinic during pregnancy [RRR = 1.139 , 95% CI = 1.079, 1.201], those whose parents delivered at home [RRR = 1.183, 95% CI = 1.137, 1.230], those whose mothers had poor wealth status [RRR = 1.297 , 95% CI = 1.25, 1.361], had middle wealth status [RRR = 1.195, 95% CI = 1.138, 1.254], had no access to media [RRR = 1.079, 95% CI = 1.042, 1.117], had no access to electricity [RRR = 1.136, 95% CI = 1.083, 1.191], used unclean type of cooking fuel [RRR = 1.177, 95% CI = 1.089, 1.271], and those from rural areas [RRR = 1.050, 95% CI = 1.006, 1.095] had higher risk of reporting one or a coexistence of two malnutrition dimensions.

Children from Burundi and Congo DR were at higher risk of developing one or co-existence of two malnutrition dimensions compared to those from Angola. Lower risk was however reported among children from the remaining countries studied except for Chad, Comoros, Nigeria, and Rwanda, where no statistical significance was found.

Co-existence of Three Dimensions of Malnutrition

Regarding the co-existence of the three dimensions of malnutrition (stunting, wasting, and underweight), age of the child, sex of the child, perceived size of birth size, maternal educational attainment, working status, antenatal visits during pregnancy, place of delivery, wealth status, access to media, and type of toilet facility were found to be

significant risk factors. The risk of co-existence of the three malnutrition dimensions decreases with the increasing age of children. Thus, children aged 1 year [RRR = 3.714 95% CI = 3.319, 4.156], 2 years [RRR = 2.739, 95% CI = 2.480, 3.222], and 3 years [RRR = 1.464, 95% CI = 1.227, 1.748] were at greater risk of having co-existence of all the three forms of malnutrition. Children who were females were less likely to have a co-existence of the three dimensions of malnutrition compared to their counterpart males [RRR = 0.468, 95% CI = 0.429, 0.510].

The risk of co-existence of the three dimensions was higher among children with average size at birth [RRR = 1.756, 95% CI = 1.574, 1.958], small size at birth [RRR = 3.818, 95% CI = 3.383, 4.308], those whose mothers had no education [RRR = 3.291, 95% CI = 1.961, 5.522], had primary education [RRR = 2.381, 95% CI = 1.417, 4.001], not working [RRR = 1.195, 95% CI = 1.086, 1.314], had no antenatal visits during pregnancy [RRR = 1.364, 95% CI =1.208, 1.541], delivered at home [RRR = 1.372, 95% CI = 1.232, 1.529], those whose mothers were poor [RRR = 1.408, 95% CI = 1.235, 1.605], had middle wealth status [RRR = 1.214, 95% CI = 1.054, 1.397], had no access to media [RRR = 1.255, 95% CI = 1.144, 1.377], and had unimproved toilet facility [RRR = 1.158, 95% CI = 1.032, 1.300].

Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having the co-existence of the three dimensions compared to those from Angola. Countries such as Benin, Cameroon, Congo, Gabon, Ghana, Guinea, Kenya, Lesotho, Malawi, Senegal, Zambia, Uganda, Tanzania, Sierra Leone, Zimbabwe, and South Africa had a lower risk among their children having co-existence of the three malnutrition dimensions (.

346 Table 2: Associations between co-existence of stunting, wasting, and underweight and predictors

Variable	Co-existed (weighted %)	95% CI	Chi²	Variable	Co-existed (weighted %)	95% CI	Chi²
Socio-demographic factors				**Access to media (tv/radio/newspaper)**			p<0.001
Age of child			p<0.001	Yes	2.14	2.0-2.2	
0	1.75	1.6-1.9		No	3.78	3.6-4.0	
1	4.44	4.2-4.7		**Urbanicity**			p<0.001
2	3.01	2.8-3.2		Urban	1.73	1.6-1.9	
3	1.62	1.4-1.8		Rural	3.21	3.1-3.3	
4	1.33	1.1-1.6		**Country**			p<0.001
Sex of child			p<0.001	Angola	2.46	2.1-2.8	
Male	3.43	3.3-3.6		Benin	2.04	1.8-2.2	
Female	1.99	1.9-2.1		Burkina Faso	5.31	4.9-5.8	
Birth order			p<0.001	Burundi	3.76	3.2-4.4	
1	2.25	2.1-2.4		Cameroon	1.27	0.9-1.7	
2 to 4	2.56	2.4-2.7		Chad	5.86	5.2-6.5	
5 and above	3.23	3.1-3.4		Comoros	1.98	1.3-2.9	
Perceived size at birth			p<0.001	Congo	0.98	0.7-1.5	
Large	1.78	1.7-1.9		Cote d'Ivoire	2.28	1.7-3.0	
Average	2.6	2.5-2.7		DR Congo	2.66	2.2-3.2	
Small	4.98	4.7-5.3		Ethiopia	3.64	3.2-4.1	
Mother's characteristics				Gabon	0.63	0.3-1.0	
Maternal age			P = 0.080	Gambia	3.61	2.4-5.2	
15-19	2.78	2.5-3.1		Ghana	1.37	0.9-2.0	

20-49	2.71	2.6-2.8		Guinea	2.26	1.7-2.9	
Educational attainment			p<0.001	Kenya	0.94	0.7-1.2	
No education	4.19	4.0-4.4		Lesotho	0.86	0.7-1.0	
Primary	2.09	2.0-2.2		Liberia	2.37	1.7-3.1	
Secondary	1.22	1.1-1.3		Malawi	1.03	0.7-1.4	
Higher	0.66	0.4-1.0		Mali	3.62	2.5-4.1	
Working status			p<0.001	Namibia	1.99	1.2-3.1	
No	3.13	3.0-3.3		Nigeria	4.1	3.7-4.6	
Yes	2.48	2.4-2.6		Rwanda	6.17	5.5-6.9	
Antenatal visits during pregnancy			p<0.001	Senegal	2.43	1.8-3.2	
No	5.41	5.0-5.8		Sierra Leone	1.94	1.4-2.5	
Yes	2.39	2.3-2.5		South Africa	0.18	0.02-0.8	
Postnatal check within 2 months			p<0.001	Tanzania	1.86	2.1-3.5	
No	2.93	2.8-3.1		Togo	2.72	2.1-3.4	
Yes	2.42	2.3-2.6		Uganda	1.2	0.8-1.7	
Place of delivery			p<0.001	Zambia	1.22	1.0-1.5	
Home	4.36	4.2-4.6		Zimbabwe	0.78	0.5-1.1	
Health facility	1.96	1.9-2.1		**Environmental factors**			
Other	2.45	1.7-3.3		**Type of toilet facility**			p<0.001
Wealth status			p<0.001	Improved	1.76	1.6-1.9	
Poor	3.46	3.3-3.6		Unimproved	3.43	3.3-3.6	
Middle	2.74	2.5-2.9		**Source of drinking water**			p<0.001
Rich	1.86	1.7-2.0		Improved	2.54	2.4-2.6	
Age of household head			p = 0.276	Unimproved	3.06	2.9-3.2	

Young-adults	2.65	2.5-2.8		**Type of cooking fuel**			p<0.001
Middle-aged adults	2.76	2.6-2.9		Clean	0.98	0.8.2-1.2	
Old-aged adults	2.8	2.6-3.1		Unclean	2.92	2.8-3.0	
Sex of household head			p<0.001	Geographic region			p<0.001
Male	2.82	2.7-2.9		Western	3.11	3.0-2.3	
Female	2.33	2.1-2.5		Eastern	2.43	2.3-2.6	
Access to electricity			p<0.001	Central	2.87	2.7-3.1	
No	3.21	3.1-3.3		South Africa	0.88	0.66-1.1	
Yes	1.61	1.5-1.7					

Table 3: Multinomial regression showing risk factors of co-existence of stunting, wasting, and underweight

	Base outcome (Ref: Normal)									
	Single and two dimensions					Co-existence of three-dimensions				
Variable	RRR	Robust SE	p-value	95% CI		RRR	Robust SE	p-value	95% CI	
Age of child (Ref:0)										
1	2.008	0.041	**<0.001**	1.930	2.089	3.714	0.213	**<0.001**	3.319	4.156
2	2.624	0.057	**<0.001**	2.514	2.739	2.827	0.189	**<0.001**	2.480	3.222
3	2.122	0.054	**<0.001**	2.018	2.231	1.464	0.132	**<0.001**	1.227	1.748
4	1.504	0.046	**<0.001**	1.417	1.597	1.051	0.120	0.664	0.840	1.315
Sex of child (Ref: Male)										
Female	0.752	0.011	**<0.001**	0.731	0.775	0.468	0.021	**<0.001**	0.429	0.510
Birth order (Ref: 1)										
2	0.938	0.022	**0.005**	0.896	0.981	1.002	0.069	0.981	0.875	1.146

5 and above	0.969	0.026	0.238	0.920	1.021	0.995	0.076	0.952	0.858	1.155
Perceived size at birth (Ref: Large)										
Average	1.320	0.023	**<0.001**	1.276	1.365	1.756	0.098	**<0.001**	1.574	1.958
Small	1.931	0.045	**<0.001**	1.846	2.020	3.818	0.235	**<0.001**	3.383	4.308
Maternal age (Ref: 15-19)			**<0.001**							
20-49	0.834	0.028	**<0.001**	0.780	0.891	0.881	0.081	0.171	0.735	1.056
Educational attainment (Ref: Higher)										
No education	2.624	0.173	**<0.001**	2.305	2.987	3.291	0.869	**<0.001**	1.961	5.522
Primary	2.189	0.142	**<0.001**	1.927	2.487	2.381	0.631	**<0.001**	1.417	4.001
Secondary	1.751	0.112	**<0.001**	1.545	1.985	1.617	0.420	0.065	0.971	2.691
Working status (Ref: Yes)										
No	1.018	0.018	0.314	0.984	1.053	1.195	0.058	**<0.001**	1.086	1.314
Antenatal visits during pregnancy (Ref: Yes)										**<0.001**
No	1.139	0.031	**<0.001**	1.079	1.201	1.364	0.085	**<0.001**	1.208	1.541
Postnatal check within 2 months (Ref: Yes)										
No	0.980	0.018	0.258	0.946	1.015	0.977	0.053	0.670	0.879	1.086
Place of delivery (Ref: Health facility)										
Home	1.183	0.024	**<0.001**	1.137	1.230	1.372	0.076	**<0.001**	1.232	1.529
Other	1.046	0.073	0.517	0.912	1.201	1.047	0.207	0.818	0.710	1.543
Wealth status (Ref: Rich)										
Poor	1.297	0.032	**<0.001**	1.235	1.361	1.408	0.094	**<0.001**	1.235	1.605
Middle	1.195	0.029	**<0.001**	1.138	1.254	1.214	0.087	**0.007**	1.054	1.397
Age of household head (Ref: Young-adult)										
Middle-aged adults	0.954	0.017	**0.008**	0.921	0.987	1.010	0.052	0.841	0.913	1.118
Old-aged adults	0.974	0.023	0.273	0.930	1.021	1.065	0.070	0.338	0.936	1.213
Sex of household head (Ref: Male)										
Female	0.977	0.019	0.223	0.940	1.015	1.035	0.060	0.548	0.925	1.159

Access to media (tv/radio/newspaper) (Ref: Yes)										
No	1.079	0.019	**<0.001**	1.042	1.117	1.255	0.059	**<0.001**	1.144	1.377
Access to electricity (Ref: Yes)										
No	1.136	0.027	**<0.001**	1.083	1.191	1.062	0.077	0.404	0.922	1.225
Type of toilet facility (Ref: Improved)										
Unimproved	1.027	0.019	0.148	0.991	1.065	1.158	0.068	**0.013**	1.032	1.300
Source of drinking water (Ref: Improved)										
Unimproved	0.959	0.016	**0.011**	0.928	0.990	0.968	0.044	0.474	0.885	1.058
Type of cooking fuel (Ref: Clean)										
Unclean	1.177	0.046	**<0.001**	1.089	1.271	1.316	0.205	0.078	0.970	1.787
Urbanicity (Ref: Urban)										
Rural	1.050	0.023	**0.024**	1.006	1.095	0.943	0.060	0.359	0.832	1.069
Country (Ref: Angola)										
Benin	0.651	0.028	**<0.001**	0.598	0.708	0.625	0.078	**<0.001**	0.489	0.798
Burkina Faso	0.952	0.046	0.304	0.866	1.046	1.946	0.241	**<0.001**	1.526	2.481
Burundi	1.580	0.084	**<0.001**	1.424	1.753	2.049	0.295	**<0.001**	1.545	2.718
Cameroon	0.669	0.041	**<0.001**	0.593	0.756	0.398	0.086	**<0.001**	0.261	0.609
Chad	0.910	0.047	0.067	0.823	1.007	1.505	0.184	**0.001**	1.184	1.913
Comoros	0.883	0.076	0.149	0.745	1.046	0.656	0.184	0.133	0.378	1.138
Congo	0.674	0.052	**<0.001**	0.580	0.783	0.472	0.127	**0.005**	0.279	0.800
Cote d'Ivoire	0.734	0.052	**<0.001**	0.638	0.844	0.739	0.153	0.144	0.492	1.109
DR Congo	1.229	0.069	**<0.001**	1.100	1.373	1.351	0.216	0.059	0.988	1.847
Ethiopia	0.810	0.045	**<0.001**	0.726	0.904	0.813	0.123	0.172	0.604	1.095
Gabon	0.495	0.044	**<0.001**	0.415	0.590	0.319	0.149	**0.014**	0.128	0.796
Gambia	0.732	0.073	**0.002**	0.603	0.889	1.001	0.246	0.997	0.618	1.620
Ghana	0.453	0.037	**<0.001**	0.386	0.531	0.545	0.126	**0.009**	0.346	0.857
Guinea	0.798	0.051	**<0.001**	0.705	0.904	0.726	0.132	**0.078**	0.509	1.036
Kenya	0.553	0.030	**<0.001**	0.498	0.615	0.321	0.055	**<0.001**	0.230	0.449
Lesotho	0.777	0.068	**0.004**	0.654	0.924	0.369	0.139	**0.008**	0.177	0.772
Liberia	0.658	0.052	**<0.001**	0.565	0.768	0.776	0.187	0.291	0.484	1.243

Malawi	0.794	0.046	**<0.001**	0.708	0.889	0.447	0.098	**<0.001**	0.291	0.687
Mali	0.600	0.031	**<0.001**	0.541	0.664	1.006	0.138	0.963	0.769	1.316
Namibia	0.680	0.063	**<0.001**	0.568	0.815	0.849	0.225	0.535	0.505	1.426
Nigeria	0.953	0.045	0.310	0.868	1.046	1.527	0.199	**0.001**	1.183	1.972
Rwanda	1.059	0.057	0.285	0.954	1.176	1.991	0.260	**<0.001**	1.541	2.571
Senegal	0.660	0.048	**<0.001**	0.572	0.761	0.643	0.129	**0.028**	0.434	0.952
Sierra Leone	0.641	0.040	**<0.001**	0.567	0.725	0.656	0.129	**0.031**	0.447	0.963
South Africa	0.788	0.087	**0.031**	0.634	0.979	0.108	0.065	**0.000**	0.033	0.352
Tanzania	0.772	0.039	**<0.001**	0.699	0.851	0.699	0.111	**0.024**	0.512	0.954
Togo	0.557	0.036	**<0.001**	0.490	0.633	0.838	0.150	0.324	0.590	1.190
Uganda	0.627	0.039	**<0.001**	0.556	0.708	0.421	0.089	**<0.001**	0.278	0.637
Zambia	0.904	0.046	**0.046**	0.818	0.998	0.519	0.092	**<0.001**	0.366	0.736
Zimbabwe	0.693	0.039	**<0.001**	0.620	0.775	0.344	0.083	**<0.001**	0.214	0.554

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DISCUSSION

The study investigated the socio-demographic and environmental risk factors of the co-existence of wasting, stunting, and underweight among children under age 5 in sub-Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The study found that the countries with the highest and lowest prevalence of co-existence of stunting, wasting, and underweight were Benin (12.14%) and Gambia (0.58%) respectively. In terms of geographic region, the highest prevalence of co-existence of stunting, wasting, and underweight was observed in Western Africa (41.78%) and the lowest prevalence in Southern Africa (5.3%). Age of the child, sex of the child, the perceived size of birth size, maternal educational attainment, working status, antenatal visits during pregnancy, place of delivery, wealth status, access to media, and type of toilet facility was also found as significant risk factors. The disparities in the prevalence among the countries and geographical regions could be attributed to the nutritional practices and beliefs practised in the countries and geographical regions. Differences in the health policies provided by governments in the various countries could also account for the disparities noted. This finding implies that countries that have high prevalence should take critical lessons from the countries that are doing well regarding the implementation of nutritional policies and interventions (e.g., increasing dietary supplementation, increasing dietary diversity) that target the reduction of the co-existence of wasting, stunting, and underweight among children under age 5 in sub-Saharan Africa[2].

Similar to previous studies[1,3] , this study found that children aged 1 year, 2 years, and 3 years were at greater risk of having co-existence of all the three forms of malnutrition compared to those aged 0. A plausible reason for this finding could be that as children grow their energy needs also increase[1], increasing their risk of having all three nutritional conditions. Altenatively, since these nutritional conditions may manifest after long durations of improper nutritional practices or undernutrition[1,3] , older children may be at higher risk of having all three nutritional conditions. The finding suggests that complementary foods given to children as they grow are inadequate. To reduce the risk of co-existence of stunting, wasting and underweight among under 5 children, the health sectors in the various countries should invest heavily in providing adequate complementary feeding to this category of children.

Corroborating the findings of other studies[1,3,31,32] , this study also found that children who were females were less likely to have a co-existence of the three dimensions of malnutrition compared to their male counterparts. An acceptable explanation for this finding could be the biological variations in morbidity between males and females at that young age[3] . It is also possible that since male children have higher birth weight compared to females, they require more energy[1,33] , which increases the risk of males having all three nutritional conditions. Moreover, male children are perceived to be hungrier than females, therefore breastfeeding alone could be insufficient or inadequate[3,34] , increasing their susceptibility to having the three nutritional conditions. The finding suggests that male children should be given critical attention in the development and implementation of nutritional programs (e.g., dietary supplementation) to mitigate the co-existence of stunting, wasting, and underweight among these male children under 5.

The study found that the risk of co-existence of the three dimensions of malnutrition was higher among children with the average size at birth and small size at birth compared to

children with large size at birth. It has been proven that malnutrition in children is partly influenced by maternal nutrition practices. Hence, mothers' appropriate nutritional behaviours during the prenatal and postnatal period is key to improve child growth. Conversely, maternal undernutrition causes low maternal BMI, which in turn affects the foetus to poor development often associated with small birth size and low birth weight[1,3,21,35] . This finding indicates that mothers of children under 5 should continuously be educated on the best nutritional practices such as exclusive breastfeeding, complementary feeding, and dietary supplementation. These strategies will help ameliorate the risk of acquiring health conditions associated with malnutrition among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no education and primary education compared to those whose mothers had higher education. Mothers who have attained higher education are better informed about improved childcare practices[36] , are more empowered to make health decisions[37] , practice good personal hygiene[37] , are more likely to use the health facility[38] , proper feeding practices[35] and childcare in times of illness[35,39] . This finding suggests that mothers with no formal or little education are neglected in nutritional programs that help to eliminate stunting, wasting, and underweight. Hence, they should be given the needed consideration to deal with this persistent health issue.

This study also found that the risk of co-existence of the three dimensions was higher among children whose mothers were not working compared to those whose mothers were working. Women's employment status indicate their ability to afford proper nutritional products and health care services[35,39] . Therefore, if mothers are not employed, the children become highly susceptible or vulnerable because mothers are unlikely to meet their nutritional needs or requirements. Mothers with children under 5 with such disadvantaged background should be given subsidies on children's nutritional products and perhaps, free access to health care services by governmental andnon-governmental organizations. This step will be significant in reducing the risks of the co-existence of stunting, wasting, and underweight among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no antenatal visits during pregnancy compared to those whose mothers had antenatal visits during pregnancy. Specifically, mothers who attend antenatal services are usually educated on the best practices of nutrition and general healthcare, which hitherto would not be known by these mothers[37] . Therefore, mothers who did not have antenatal visits may lack some knowledge about proper nutritional practices, increasing their children's risk of having these malnutrition related challenges. Regular antenatal visits could reduce children's risk of having stunting, underweight, and wasting, therefore, mothers should continuously be encouraged to go for antenatal care services in their countries.

Children who were delivered at home compared to children who were delivered at a health facility were found to have a higher risk of co-existence of the three dimensions. Since mothers who deliver at home do not receive any expert nutritional advice from a qualified health practitioner[36] , the children of such mothers are at higher risk of having these conditions because poor and/ or inadequate dietary practices. This finding shows that facility delivery may help reduce the risk of co-existence of stunting, wasting, and

underweight among children under 5. Therefore, mothers should regularly be educated on the need to opt for facility delivery because its positive implications on children's growth. .

The risk of co-existence of the three dimensions was higher among children whose mothers were poor and had middle wealth status compared to those whose mothers were rich. Usually, mothers who have average income may lack the financial capacity to feed themselves and their children properly and adequately[3,17,35] , increasing the children's risk of being stunted, underweight or wasted. Likewise, mothers from poor and middle wealth quintile may not have access to quality nutritional products and health care systems[35,39] , making their children more susceptible to having all three nutritional conditions. This finding implies that women from poor economic backgrounds should be assisted with nutritional products and services to facilitate the reduction in the risks of the co-existence of stunting, wasting, and underweight among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no access to media compared to those whose mothers had access to media. Since many people are educated about proper nutritional practices through the mass media[10,11] , mothers who have no access to the media may lack certain important nutritional information they need. This information gap could increase children's risk of having all three nutritional conditions through improper dietary practices from their mothers. For instance, mothers' access to appropriate information from the media would help them decide on which proper diets or food commodities are readily available on market for their children. More pragmatic ways of reaching mothers who have no access to media are encouraged. Regular outreach or sensitization programs to target women without access to media for example could help in reducing the risks of the co-existence of stunting, wasting, and underweight among children under 5.

Children whose mothers had unimproved toilet facilities were found to have a higher risk of co-existence of the three dimensions of child malnutrition compared to those whose mothers had improved toilet facility. Insanitary or unhygienic toilet conditions may increase mother-child-environment interactions that may result in increased exposure to childhood diseases and other opportunistic infections (e.g., diarrhoeal episodes, fever) either through consumption of contaminated foods, drinking water or poor environmental sanitation[21] . These conditions have been shown to cause growth retardation in children. Governmental and non-governmental organizations should support with the provision of improved household toilet facilities for poorer communities to help minimize the risks of the co-existence of child malnutrition indicators.

Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having the co-existence of the three dimensions compared to those from Angola. On the other hand, countries such as Benin, Cameroon, Congo, Gabon, Ghana, Guinea, Kenya, Lesotho, Malawi, Senegal, Zambia, Uganda, Tanzania, Sierra Leone, Zimbabwe, and South Africa had a lower risk among their children having co-existence of the three malnutrition dimensions. The sub-regional and country-specific variations in socio-economic, agro-ecological and geographical characteristics may strongly influence the nutritional status of children because inadequate food supplies, limited access to arable land for agriculture, unfavorable climatic conditions (e.g., desertification), rapid population growth, and increasing cost of living may determine food access, availability and production in studied

countries in SSA[40,41] . Governmental priorities should intensify efforts to minimize the risk of co-existence of stunting, wasting, and underweight among children under age 5 with sound socio-economic and sustainable human capital development.

Conclusions

The study investigated the socio-demographic and environmental risk factors of the co-existence of wasting, stunting, and underweight among children under age 5 in sub-Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The study found that the prevalence of co-existence of stunting, wasting, and underweight ranged from 0.58 % in the Gambia to 12.14% in Benin. The study also found that the prevalence of co-existence of stunting, wasting, and underweight was high in Western Africa (41.78%) but low in Southern Africa (5.3%). The significant findings show that the disadvantaged have more risks of the co-existence of wasting, stunting and underweight among under 5 children in selected SSA countries. Findings require context nutrition-specific interventions such as complimentary feeding, dietary supplementation and increasing dietary diversity to promote children feeding practices across the studied countries. Besides, country-specific sustainable human capital developmental agenda (e.g., empowerment initiatives, entrepreneurial training), especially among mothers is required to help improve children's dietary intake by governments and partnering institutions or agencies.

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Ethics Approval and consent to participate

DHS reports ethical clearance are provided by the Ethics Committee of ORC Macro Inc. as well as Ethics Boards of partner institutions (e.g., Ministries of Health) from studied countries. The DHS procedures require that principles for the protection of respondents' anonymity and confidentiality are adhered. Inner City Fund International also guarantees that the survey protocols meet the United States Department of Health and Human Services' regulations for the respect of human subjects. The current study used a secondary data, hence, no further ethical approval was sought. The datasets are freely available for download and usage at https://dhsprogram.com/data/available-datasets.cfm.

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Data availability statement: Data are available in a public, open access repository. Data for this study were sourced from Demographic and Health surveys (DHS) and available here: http://dhsprogram.com/data/available-datasets.cfm

References

1. Amare ZY, Ahmed ME, Mehari AB. Determinants of nutritional status among children under age 5 in Ethiopia: further analysis of the 2016 Ethiopia demographic and health survey. *Global Health* 2019;15(1):1–11.
2. Anin SK, Saaka M, Fischer F, Kraemer A. Association between Infant and Young Child Feeding (IYCF) Indicators and the Nutritional Status of Children (6–23 Months) in Northern Ghana. Nutrients *2020;* 12, 2565. https://doi.org/10.3390/nu12092565
3. Madiba S, Chelule PK, Mokgatle MM. Attending informal preschools and daycare centers is a risk factor for underweight, stunting and wasting in children under the age of five years in underprivileged communities in South Africa. *International Journal of Environmental Research and Public Health* 2019; 16(14), 2589.
4. Yalew BM, Amsalu F, Bikes D. Prevalence and factors associated with stunting, underweight and wasting: a community based cross sectional study among children age 6-59 months at Lalibela Town, Northern Ethiopia. *J Nutr Disorders Ther* 2014; 4(147), 2161-0509.
5. WHO. Nutrition Landscape Information System (NLIS) Country Profile Indicators: Interpretation Guide; World Health Organization: Geneva, Switzerland, 2010.
6. Akombi BJ, Agho KE, Hall JJ, Wali N, Renzaho A, Merom D. Stunting, wasting and underweight in sub-Saharan Africa: a systematic review. *International Journal of Environmental Research and Public Health* 2017; 14(8), 863.
7. WHO. Global nutrition targets 2025: policy brief series (WHO/NMH/NHD/14.2). Geneva: World Health Organization; 2014. https://apps.who.int/iris/bitstream/handle/10665/149018/WHO_NMH_NHD_14.2_eng.pdf
8. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, Ezzati M, Grantham-McGregor S, Katz J, Martorell R, Uauy R, Maternal and Child Nutrition Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries. *The lancet* 2013; 382(9890), 427-451.
9. World Health Organization. Levels and trends in child malnutrition: key findings of the 2019 edition (No. WHO/NMH/NHD/19.20). World Health Organization. 2019.
10. De Onis M, Onyango A, Borghi E, Siyam A, Blössner M, Lutter C. Worldwide implementation of the WHO child growth standards. *Public Health Nutrition* 2012; 15(9), 1603-1610.
11. De Onis M, Blössner M, Borghi E. Prevalence and trends of stunting among pre-school children, 1990–2020. *Public Health Nutrition* 2012; 15(1), 142-148.
12. World Health Organization. Community-based management of severe acute malnutrition: a joint statement by the World Health Organization, the World Food

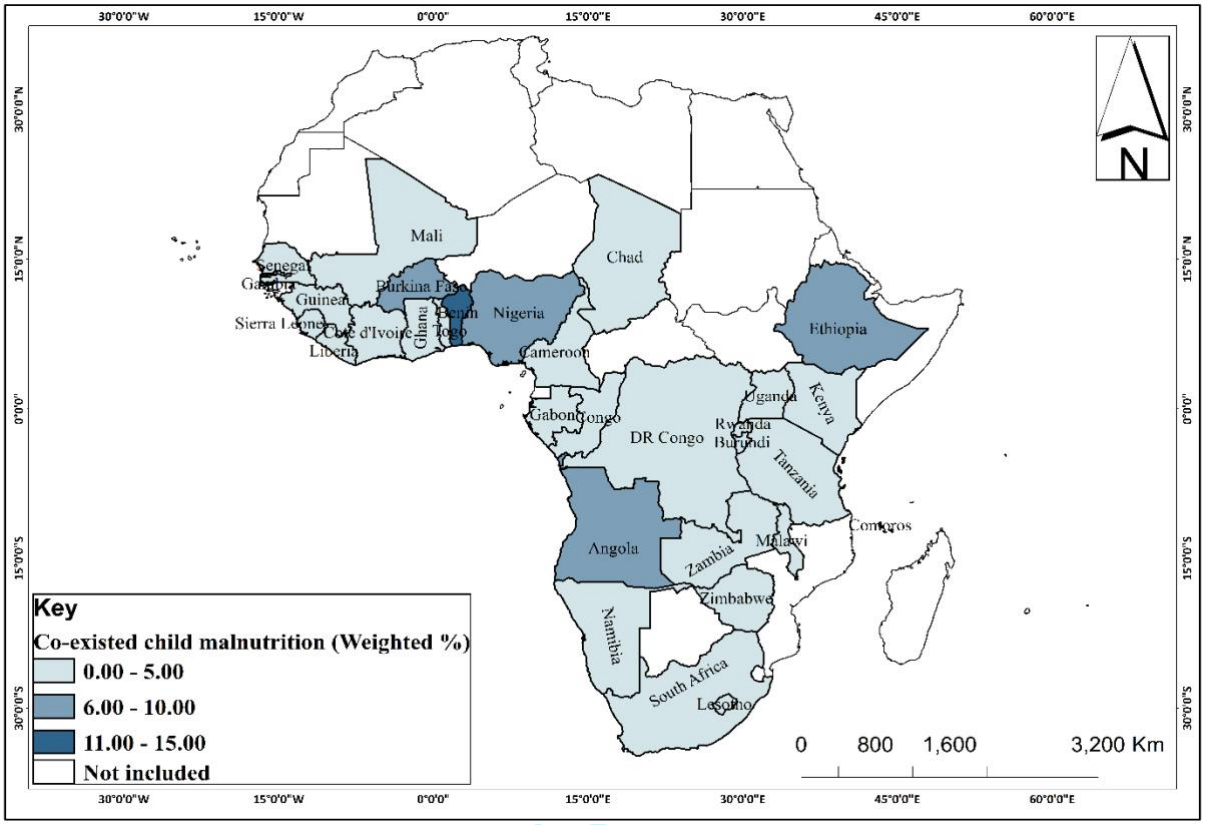
Programme, the United Nations System Standing Committee on Nutrition and the United Nations Children's Fund. 2007.
13. UNICEF. Levels and trends in child malnutrition, United Nations Children's fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and trends in child malnutrition: key findings of the 2019 edition of the joint child malnutrition estimates. Geneva: World Health Organization; 2019 Licence: CC BY-NC-SA 3.0 IGO; 2019.
14. Central Statistical Agency (CSA)[Ethiopia] and ICF. Ethiopia demographic and health survey, Addis Ababa, Ethiopia and Calverton, Maryland, USA. 2016.
15. Yaya S, Uthman OA, Ekholuenetale M, Bishwajit G, Adjiwanou V. Effects of birth spacing on adverse childhood health outcomes: evidence from 34 countries in sub-Saharan Africa. *J Matern & Neonatal Med* 2020;33(20):3501–8.
16. Armah FA, Ekumah B, Yawson DO, Odoi JO, Afitiri A, Nyieku FE, et al. Predictive Probabilities of Access to Clean Cooking: Evidence from the Demographic and Health Surveys in 31 Countries in Sub-Saharan Africa. 2019;12(3):320–2.
17. Mamabolo RL, Alberts M, Steyn NP, Delemarre-van de Waal HA, Levitt NS. Prevalence and determinants of stunting and overweight in 3-year-old black South African children residing in the Central Region of Limpopo Province, South Africa. *Public Health Nutrition* 2005; 8(5), 501-508.
18. Novignon J, Aboagye E, Agyemang OS, Aryeetey G. Socioeconomic-related inequalities in child malnutrition: evidence from the Ghana multiple indicator cluster survey. *Health Economics Review* 2015; 5(1), 1-11.
19. Bain LE, Awah PK, Geraldine N, Kindong NP, Siga Y, Bernard N, Tanjeko AT. Malnutrition in Sub–Saharan Africa: burden, causes and prospects. *Pan African Medical Journal* 2013; 15(1).
20. Fanzo J. The nutrition challenge in sub-Saharan Africa (No. 2012-012). United Nations Development Programme, Regional Bureau for Africa. 2012.
21. Akombi BJ, Agho KE, Merom D, Renzaho AM, Hall JJ. Child malnutrition in sub-Saharan Africa: A meta-analysis of demographic and health surveys (2006-2016). *PLoS One* 2017;12(5): e0177338.
22. World Health Organization. United Nations Children's Fund (2009) WHO child growth standards and the identification of severe acute malnutrition in infants and children A Joint Statement. World Health Organization. 2014; 11.
23. Corsi DJ, Neuman M, Finlay JE, Subramanian SV. Demographic and health surveys: a profile. *International Journal of Epidemiology* 2012; 41(6), 1602-1613.
24. Aliaga A, Ruilin R. Cluster optimal sample size for demographic and health surveys. In 7th International Conference on Teaching Statistics–ICOTS (Vol. 7, pp. 2-7). 2006.
25. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, Strobe Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. International journal of surgery. 2014; 12(12), 1495-1499.
26. Collins J, Ward BM, Snow P, Kippen S, Judd F. Compositional, Contextual, and Collective Community Factors in Mental Health and Well-Being in Australian Rural Communities. *Qualitative Health Research* 2017; 27(5), 677–687. https://doi.org/10.1177/1049732315625195
27. Pol LG, Thomas RK. The demography of health and health care. Springer Science & Business Media. 2001.

28. Armah FA, Ekumah B, Yawson DO, Odoi JO, Afitiri AR, Nyieku F.E. Access to improved water and sanitation in sub-Saharan Africa in a quarter century. *Heliyon* 2018; 4(11), e00931. https://doi.org/10.1016/j.heliyon.2018.e00931
29. Ross CE, Mirowsky J. Neighborhood socioeconomic status and health: context or composition? *City & Community* 2008; 7(2), 163–179.
30. Amegah AK, Boachie J, Näyhä S, Jaakkola JJK. Association of biomass fuel use with reduced body weight of adult Ghanaian women. *J Expo Sci Environ Epidemiol* 2019;1.
31. Alemayehu M, Tinsae F, Haileslassie K, Seid O, Gebregziabher G, Yebyo H. Undernutrition status and associated factors in under-5 children, in Tigray, Northern Ethiopia. *Nutrition* 2015; 31(7-8), 964-970.
32. Mya KS, Kyaw AT, Tun T. Feeding practices and nutritional status of children age 6-23 months in Myanmar: A secondary analysis of the 2015-16 Demographic and Health Survey. *PloS one* 2019; 14(1), e0209044.
33. Bork KA, Diallo A. Boys are more stunted than girls from early infancy to 3 years of age in rural Senegal. *The Journal of Nutrition* 2017; 147(5), 940-947.
34. Tumilowicz A, Habicht JP, Pelto G, Pelletier DL. Gender perceptions predict sex differences in growth patterns of indigenous Guatemalan infants and young children. *The American Journal of Clinical Nutrition* 2015; 102(5), 1249-1258.
35. Mukabutera A, Thomson DR, Hedt-Gauthier BL, Basinga P, Nyirazinyoye L, Murray M. Risk factors associated with underweight status in children under five: an analysis of the 2010 Rwanda Demographic Health Survey (RDHS). *BMC Nutrition* 2016; 2(1), 1-12.
36. Oyekale AS. Factors explaining acute malnutrition among under-five children in Sub-Sahara Africa (SSA). *Life Sci J* 2012; 9, 2101-7.
37. Keats A. Women's schooling, fertility, and child health outcomes: Evidence from Uganda's free primary education program. *Journal of Development Economics* 2018; 135, 142-159.
38. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Poor nutrition status and associated feeding practices among HIV-positive children in a food secure region in Tanzania: a call for tailored nutrition training. *PloS one* 2014; 9(5), e98308.
39. Iannotti LL, Dulience SJL, Green J, Joseph S, François J, Antenor ML, ... Nickerson NM. Linear growth increased in young children in an urban slum of Haiti: a randomized controlled trial of a lipid-based nutrient supplement. *The American Journal of Clinical Nutrition* 2014; 99(1), 198-208.
40. Lopriore C, Muehlhoff E. Food security and nutrition trends in West Africa—Challenges and the way forward. In Proceedings of the 2nd International Workshop on Food-based Approaches for a Healthy Nutrition, Ouagadougou, Burkina. 2003; 23–28.
41. Salami A, Kamara AB, Brixiova Z. Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities; African Development Bank: Tunis, Tunisia, 2010.

Figure legends

Figure 1: Percentage distribution of co-existed child malnutrition in the 31 study countries in SSA

Figure 2: Proportional circle map showing the percentage distribution of co-existed child malnutrition in study countries by regions of SSA



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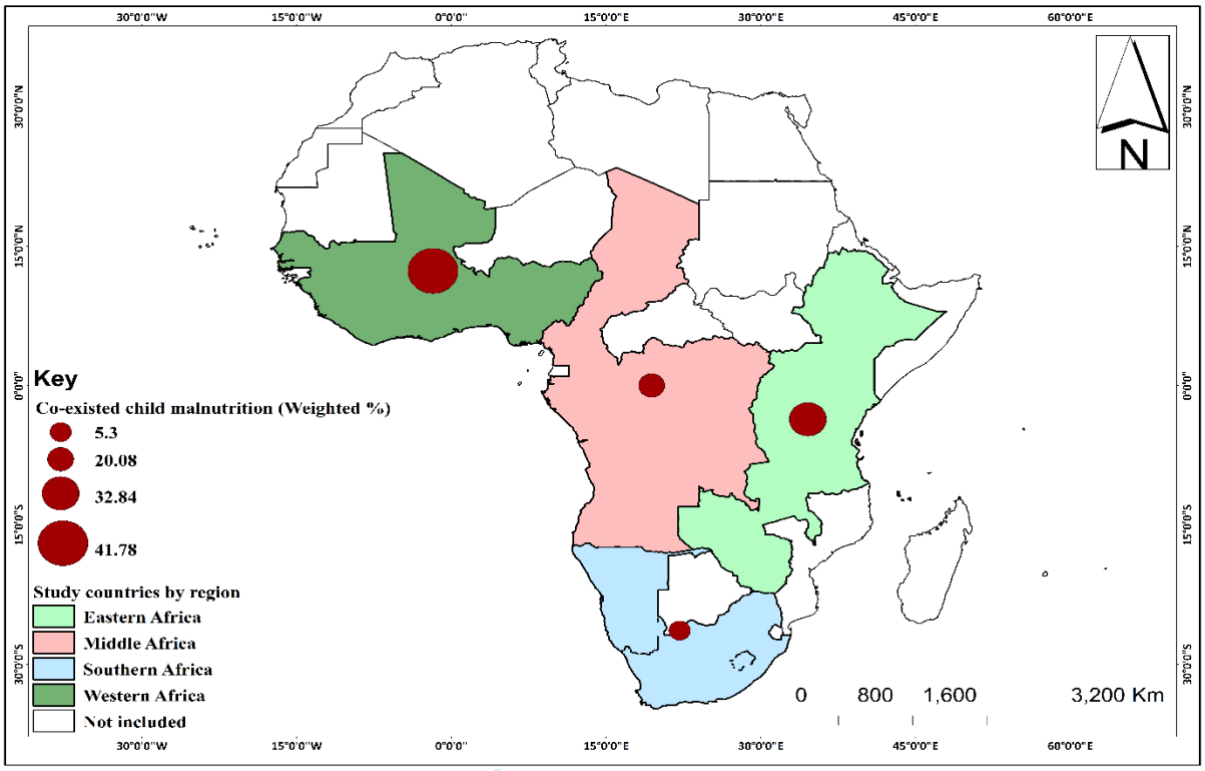

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Socio-demographic and environmental risk factors accounting for the co-existence of stunting, underweight, and wasting in children under five: Analysis of cross-sectional surveys from 31 sub-Saharan African countries

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Socio-demographic and environmental risk factors accounting for the co-existence of stunting, underweight, and wasting in children under five: Analysis of cross-sectional surveys from 31 sub-Saharan African countries

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ABSTRACT

Objective: This study investigated the socio-demographic and environmental risk factors of the co-existence of stunting, underweight, and wasting among children under age five in sub-Saharan Africa.

Methods: Data from 31 sub-Saharan African countries were pooled from the Demographic and Health Surveys (DHS) collected between 2010 and 2019. We examined the risk of co-existence of undernutrition using multinomial logistic regression models, with results presented as relative risk ratios (RRR) with their respective confidence intervals.

Outcome measures: The outcome variables were three child anthropometrics: stunting (height-for-age z-scores); underweight (weight-for-age z-scores); and wasting (weight-for-height z-scores).

Results: The prevalence of co-existence of stunting, underweight, and wasting varied across countries and sub-regions, with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting as Benin (12.14%) and Gambia (0.58%) respectively. The risk of co-existence of the three undernutrition dimensions was higher among children age 1 year compared to those aged 0. Children who were females were less likely to have a co-existence of the three dimensions of undernutrition compared to their male counterparts. The risk of co-existence of the three dimensions was higher among children with small size at birth, those whose mothers had no education, not working, had no antenatal visits during pregnancy, children delivered at home, those whose mothers were poor had no access to media, and children whose mothers had unimproved toilet facility.

Conclusion: Findings suggest context nutrition-specific interventions such as complementary feeding, dietary supplementation and increasing dietary diversity to promote children feeding practices in the studied countries are warranted. Planned interventions should prioritize all the identified factors noted in the current study to help reduce the risks of co-existence of stunting, underweight, and wasting among children under age 5.

Keywords: co-existence; stunting; underweight; wasting; children under five; sub-Saharan Africa

Strength and Limitations

- The use of nationally representative data ensures that our findings are generalizable and replicable in the 31 SSA countries included in this study.
- Findings contribute to bridging the gaps identified in the current research on CNS by including multiple indicators (stunting, underweight, and wasting) in the concurrent measurement of our outcome variable, compared to the unitary assessment on undernutrition that currently dominates literature.
- The study relied on secondary data, the analysis was limited to only variables that were in the dataset. Hence, interpretations and inferences made from current findings must be limited to only these observed variables.
- Also, the DHS employs cross-sectional designs which restrict causality on the noted outcomes.
- The key variables were self-reported by the mothers, and therefore, there is the likelihood of recall bias and other social desirability concerns in the present study.

BACKGROUND

Undernutrition among children under 5 years remains a major public health problem across many developing countries[1-3]. Factors such as insufficient food intake, diarrhoea, recurring infections, poor sanitation practices, and low parental education have been identified as significant contributors to the high prevalence of undernutrition during childhood[1,4,5]. Despite the numerous interventions rolled out to address childhood undernutrition especially in sub-Saharan Africa where the phenomenon is quite pervasive, the progress seems to be insignificant[6,7]. For example, a study reported that child undernutrition accounted for nearly half (45%) of the child mortality rate in developing countries[8]. Aside from that, it was reported in 2018 that about 149 million and 49 million children under age 5 were stunted and wasted respectively[9].

Three main indicators that are often used to represent undernutrition are underweight or low weight for age, stunting or low height for age, and wasting or low weight for height[2,10-12]. Among the three indicators of undernutrition, stunting has been identified as the problem with the greatest magnitude among under 5 children in developing countries[2,3]. Even though the prevalence of stunting in sub-Saharan Africa is declining, it is worth noting that it is still above 30%[13] which is undeniably high. Research also indicates that the country-specific prevalence of stunting, underweight and wasting is still high[2,3]. For instance, in Ethiopia, the prevalence of wasting and stunting were 10% and 38% respectively[14]. Additionally, the prevalence of stunting, underweight and wasting among children in South Africa were 35.8%, 20.5%, and 17.2%[3]. Likewise, Anin et al.[2] reported 33.2%, 14.1%, 27% and 2.6% of prevalence in stunting, wasting, underweight and overweight among infants (6-23 months) across Northern Ghana.

Previous studies have investigated the socio-demographic and environmental risk factors associated with either stunting, underweight or wasting among children under 5 years and found the age of a child, sex of the child, child's size at birth, mother's age during childbirth, mother's educational level, birth order, place of residence and mother's body mass index (BMI) as associated factors[1-3,15,16] . Other studies also found a significant linkage between household wealth quintile and maternal short stature, and nutritional status of children under 5[17,18] . Regarding the sex of a child, for example, female children were found to be less likely to suffer from stunting compared to males[1,3] .

Apart from studies that have examined the factors associated with either stunting, underweight, and wasting, some scholars have begun looking at predictors of the co-existence of any two or three of the indicators of malnutrition. A study in 84 countries that examined the prevalence and predictors of co-existence of stunting and wasting found sex and age of children as significant predictors[19]. Other studies in Ghana[20] and India[21] also examined the co-existence of stunting, underweight, and wasting and found birth interval, birth weight, dietary diversity, place of delivery, wealth index, mother's BMI, mother's educational level, and partners' educational level as associated factors. The need to examine the co-existence of stunting, underweight and wasting is important because not much work has been done on that subject and hence children who concurrently suffer from stunting, underweight, and wasting are less likely to be reached in malnutrition prevention programmes, especially in SSA. For instance, some scholars have indicated that despite evidence that wasting and stunting are global public health problems that frequently co-exist, they are usually separated in terms of policy, guidance, programming

and financing[22]. This creates a gap in literature that needs to be filled. Despite the detrimental consequences of undernutrition on the health and wellbeing of children under 5 in SSA, few studies have utilised current nationally representative data from a larger sample to investigate the socio-demographic and environmental risk factors associated with the co-existence of stunting, underweight, and wasting among this age group. Studies presenting empirical analyses of the co-existence of these three indicators of child undernutritionin SSA are absent in extant literature making it difficult for policymakers and nutritional experts to provide up-to-date trends with appropriate strategies to curb the situation in the sub-region. This research lag presents a void in extant literature which this study seeks to bridge. Therefore, the study investigated the socio-demographic and environmental risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from the Demographic Health Survey (DHS) conducted in 31 countries between 2010 and 2019. The findings of the study could contribute to the formulation of policies and interventions to respond to the nutritional needs of children under 5 years and also suggest pragmatic ways of reducing undernutrition among children in the sub-region.

METHODS

Data Source

The dataset included 127,487 children under the age of 5 years from 31 sub-Saharan African countries (Figure 1) were pooled from the most current Demographic and Health Surveys (DHS) conducted between 2010 and 2019 (Appendix 1). Specifically, the data were pooled from the children's files in each of the countries. The DHS Program has conducted over 400 surveys in over 90 developing countries around the world since 1984 every five years[23]. The program implements cross-sectional surveys to gather nationally-representative data, analyze and disseminate accurate information on important demographic and health indicators spanning population, nutrition, and diseases. For all surveys, standardized protocols designed for each target group including children, women, and men at the household level are employed to allow for cross-national comparisons. Stratified two-stage sampling involving first, the listing of enumeration areas and selection of clusters, and then a random selection of households in each cluster. The detailed sampling method can be found in a previous study[24]. The dataset is freely available for download at: https://dhsprogram.com/data/available-datasets.cfm. The Strengthening Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed in writing the manuscript[25] .

Study Variables

Outcome Variable

The outcome variable considered in this study is derived from three child anthropometric variables including stunting (height-for-age z-scores); underweight (weight-for-age z-scores) and wasting (weight-for-height z-scores). The DHS (2021) specifies categorization for each of these variables following the WHO child growth standard. Each of the three variables we coded into "0" for "Normal" and "1" for "Stunting", "underweight" and "Wasting" respectively.

These three variables were then added to generate the outcome variable "Co-existed undernutrition" with scores (discrete) ranging from 0 to 4 where 0 implies "Normal", that is, children with none of the three conditions; 1 implies "Single burden", that is, the child suffers from one of the three conditions; 2 indicates that child suffers from "Two burdens" out of the three; and 3 shows "Co-existed", that is, the child suffers from all three conditions of undernutrition. For parsimony, children who suffered from "Single burden" and those who suffered from "Two burdens" were added resulting in the variable "Co-existed undernutrition" with three response categories: 0=Normal; 1=One or two burdens; and 3=co-existed.

Independent Variables

Several risk factors spanning socio-demographic and environmental factors have been associated with child undernutrition. The relevant biosocial characteristics and sociocultural factors related to the child, mother, household head and the household together form compositional factors[26,27]. Factors that describe location or "place-based" variables are contextual factors[20,26,28,29]. In this study, contextual and composition factors except household-level characteristics related to environment and sanitation are categorized as "Socio-demographic risk factors". Socio-cultural household characteristics related to environment and sanitation are categorized as "Environmental risk factors".

Socio-Demographic Risk Factors

The relevant variables under socio-demographic risk factors considered include the age of the child; sex of child; birth order of child ; perceived size at birth; mother's age; educational attainment; working status; antenatal visits during pregnancy; postnatal check within 2 months; and place of delivery. At the household level, relevant variables included are the wealth status; the age of household head ; sex of household head (male and female); access to electricity ; and access to media which was derived from the three variables "access to television", "radio" and "newspaper". The contextual factors considered are Urbanicity and the country of origin of the participant.

Environmental Risk Factors

We considered the following variables: type of toilet facility (re-coded into "improved" and unimproved"[28]; source of drinking water (re-coded as "improved" and "unimproved"[28]; and type of household cooking fuel (re-coded into "clean" and "unclean" [28,30]under the category "environmental risk factors"

Data Analyses

The statistical analysis of the data was performed using the Stata SE software version 14.2. The "svyset" command was first used to declare the data as survey data to prevent the potential effects of the complex sampling techniques on the analyses. To understand the distributions of the variables, the data were summarized and presented in tables using descriptive statistics (frequencies, weighted percentages, and 95% confidence intervals (CIs) of percentages). We further integrated the data into a GIS environment and presented the distribution of key variables across the study countries and geographic regions in map images (Figure 1 and Figure 2). This approach enhances the visualization of the data and understanding of the context of the study. The associations between the co-existence of undernutrition and each of the risk factors considered were assessed using

the chi-square test of independence, with results presented in a contingency table. The risk factors as independent variables were then subjected to collinearity diagnosis tests, including Variance Inflation Factors (VIF), Square VIF, Tolerance, and R-squared (See Appendix 2). To determine the socio-demographic and environmental risk factors associated with the co-existence of undernutrition, a multinomial regression model was implemented. The sample weight variable was used to adjust for potential over-and under-sampling. All statistical tests were conducted at $p<0.05$.

Ethical Approval

DHS reports ethical clearance is provided by the Ethics Committee of ORC Macro Inc. as well as Ethics Boards of partner institutions (e.g., Ministries of Health) from studied countries. The DHS procedures require that principles for the protection of respondents' anonymity and confidentiality adhere. Inner City Fund International also guarantees that the survey protocols meet the United States Department of Health and Human Services' regulations for the respect of human subjects. The current study used secondary data, hence, no further ethical approval was sought. The datasets are freely available for download and usage at https://dhsprogram.com/data/available-datasets.cfm.

Table 1

Figure 1

Figure 2

Patient and public involvement

Patients and the public were not involved in the design and conduct of this research

Results

Descriptive Analysis on the Prevalence of Co-existence of Stunting, Underweight, and wasting varied across Countries and Sub-Regions

Table 1 shows the description of the sample in the study across the independent variables. Appendix 2 shows the distribution of sample by country. The prevalence of co-existence of stunting, underweight, and underweight varied across countries and sub-regions, with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting as Rwanda (6.17%) and South Africa (0.18%) respectively (Figure 1). In terms of sub-region, the highest prevalence of co-existence of stunting, underweight, and wasting was observed in Western Africa (3.11%) and the lowest prevalence in Southern Africa (0.88%) (Figure 2). Significant associations between all the independent variables and co-existence of stunting, wasting, and underweight, except maternal age and age of household head, were identified (Table 2).

Table 2

Multinomial Logistic Regression Results of Risk Factors for Co-existence of One and a Co-Existence of Two Dimensions of Undernutrition

Table 3 shows the results of the multinomial regression analysis of the risk factors of co-existence of dimensions of undernutrition (stunting, underweight, and wasting) among children under five years in the SSA. Age of child, size of the child at birth, sex of the child,

birth order, educational level, maternal age, ANC attendance, place of delivery, source of drinking water, sex of household head, wealth index, access to electricity and place of residence were associated with one or two dimensions of undernutrition. See Appendix 3 for country-level risk of co-existence of stunting, wasting, and underweight.

Co-existence of Three Dimensions of Undernutrition

Regarding the co-existence of the three dimensions of undernutrition (stunting, underweight, and wasting), age of the child, sex of the child, perceived size of birth size, maternal educational attainment, working status, antenatal visits during pregnancy, place of delivery, wealth status, access to media, and type of toilet facility were found to be significant risk factors (Table 3).

*****Table 3*****

DISCUSSION

The study investigated the socio-demographic and environmental risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The study found that the countries with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting were Benin and Gambia respectively. In terms of geographic region, the highest prevalence of co-existence of stunting, underweight, and wasting was observed in Western Africa and the lowest prevalence in Southern Africa. The disparities in the prevalence among the countries and geographical regions could be attributed to the nutritional practices and beliefs practised in the countries and geographical regions. Differences in the health policies provided by governments in the various countries could also account for the disparities noted. This finding implies that countries that have high prevalence should take critical lessons from the countries that are doing well regarding the implementation of nutritional policies and interventions (e.g., increasing dietary supplementation, increasing dietary diversity) that target the reduction of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa[2].

Similar to previous studies[1,3], this study found that children aged 1 year, 2 years, and 3 years were at greater risk of having co-existence of all the three forms of undernutrition compared to those aged 0. A plausible reason for this finding could be that as children grow their energy needs also increase[1], increasing their risk of having all three nutritional conditions. Alternatively, since these nutritional conditions may manifest after long durations of improper nutritional practices or undernutrition[1,3] , older children may be at higher risk of having all three nutritional conditions. The finding suggests that complementary foods given to children as they grow are inadequate. To reduce the risk of co-existence of stunting, underweight, and wasting among under 5 children, the health sectors in the various countries should invest heavily in providing adequate complementary feeding to this category of children.

Corroborating the findings of other studies[1,3,31,32], this study also found that children who were females were less likely to have a co-existence of the three dimensions of undernutrition compared to their male counterparts. An acceptable explanation for this

finding could be the biological variations in morbidity between males and females at that young age[3]. It is also possible that since male children have higher birth weight compared to females, they require more energy[1,33], which increases the risk of males having all three nutritional conditions. Moreover, male children are perceived to be hungrier than females, therefore breastfeeding alone could be insufficient or inadequate[3,34], increasing their susceptibility to having the three nutritional conditions. The finding suggests that male children should be given critical attention in the development and implementation of nutritional programs (e.g., dietary supplementation) to mitigate the co-existence of stunting, underweight, and wasting among these male children under 5.

The study found that the risk of co-existence of the three dimensions of undernutrition was higher among children with the average size at birth and small size at birth compared to children with large size at birth. It has been proven that undernutrition in children is partly influenced by maternal nutrition practices. Hence, mothers' appropriate nutritional behaviours during the prenatal and postnatal period is key to improve child growth. Conversely, maternal undernutrition causes low maternal BMI, which in turn affects the foetus to poor development often associated with a small birth size and low birth weight[1,3,21,35]. This finding indicates that mothers of children under 5 should continuously be educated on the best nutritional practices such as exclusive breastfeeding, complementary feeding, and dietary supplementation. These strategies will help ameliorate the risk of acquiring health conditions associated with undernutrition among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no education and primary education compared to those whose mothers had higher education. Mothers who have attained higher education are better informed about improved childcare practices[36] , are more empowered to make health decisions[37] , practice good personal hygiene[37] , are more likely to use the health facility[38] , proper feeding practices[35] and childcare in times of illness[35,39] . This finding suggests that mothers with no formal or little education are neglected in nutritional programs that help to eliminate stunting, underweight, and wasting . Hence, they should be given the needed consideration to deal with this persistent health issue.

This study also found that the risk of co-existence of the three dimensions was higher among children whose mothers were not working compared to those whose mothers were working. Women's employment status indicates their ability to afford proper nutritional products and health care services[35,39]. Therefore, if mothers are not employed, the children become highly susceptible or vulnerable because mothers are unlikely to meet their nutritional needs or requirements. Mothers with children under 5 with such disadvantaged backgrounds should be given subsidies on children's nutritional products and perhaps, free access to health care services by governmental and non-governmental organizations. This step will be significant in reducing the risks of the co-existence of stunting, underweight, and wasting among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no antenatal visits during pregnancy compared to those whose mothers had antenatal visits during pregnancy. Specifically, mothers who attend antenatal services are usually educated on the best practices of nutrition and general healthcare, which hitherto would not be known by these mothers[37]. Therefore, mothers who did not have antenatal

visits may lack some knowledge about proper nutritional practices, increasing their children's risk of having these undernutrition -related challenges. Regular antenatal visits could reduce children's risk of stunting, underweight, and wasting, therefore, mothers should continuously be encouraged to go for antenatal care services in their countries.

Children who were delivered at home compared to children who were delivered at a health facility were found to have a higher risk of co-existence of the three dimensions. Since mothers who deliver at home do not receive any expert nutritional advice from a qualified health practitioner[36], the children of such mothers are at higher risk of having these conditions because of poor and/ or inadequate dietary practices. This finding shows that facility delivery may help reduce the risk of co-existence of stunting, underweight, and wasting among children under 5. Therefore, mothers should regularly be educated on the need to opt for facility delivery because of its positive implications on children's growth.

The risk of co-existence of the three dimensions was higher among children whose mothers were poor and had middle wealth status compared to those whose mothers were rich. Usually, mothers who have an average income may lack the financial capacity to feed themselves and their children properly and adequately[3,17,35], increasing the children's risk of being stunted, underweight or wasted. Likewise, mothers from poor and middle wealth quintiles may not have access to quality nutritional products and health care systems[35,39], making their children more susceptible to having all three nutritional conditions. This finding implies that women from poor economic backgrounds should be assisted with nutritional products and services to facilitate the reduction in the risks of the co-existence of stunting, underweight, and wasting among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no access to media compared to those whose mothers had access to media. Since many people are educated about proper nutritional practices through the mass media[10,11], mothers who have no access to the media may lack certain important nutritional information they need. This information gap could increase children's risk of having all three nutritional conditions through improper dietary practices from their mothers. For instance, mothers' access to appropriate information from the media would help them decide on which proper diets or food commodities are readily available on market for their children. More pragmatic ways of reaching mothers who have no access to media are encouraged. Regular outreach or sensitization programs to target women without access to media for example could help in reducing the risks of the co-existence of stunting, underweight, and wasting among children under 5.

Children whose mothers had unimproved toilet facilities were found to have a higher risk of co-existence of the three dimensions of child undernutrition compared to those whose mothers had improved toilet facilities. Insanitary or unhygienic toilet conditions may increase mother-child-environment interactions that may result in increased exposure to childhood diseases and other opportunistic infections (e.g., diarrhoeal episodes, fever) either through consumption of contaminated foods, drinking water or poor environmental sanitation[21]. These conditions have been shown to cause growth retardation in children. Governmental and non-governmental organizations should support the provision of improved household toilet facilities for poorer communities to help minimize the risks of the co-existence of child undernutrition indicators.

Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having the co-existence of the three dimensions compared to those from Angola. On the other hand, countries such as Benin, Cameroon, Congo, Gabon, Ghana, Guinea, Kenya, Lesotho, Malawi, Senegal, Zambia, Uganda, Tanzania, Sierra Leone, Zimbabwe, and South Africa had a lower risk among their children having co-existence of the three undernutrition dimensions. The sub-regional and country-specific variations in socio-economic, agro-ecological and geographical characteristics may strongly influence the nutritional status of children because of inadequate food supplies, limited access to arable land for agriculture, unfavourable climatic conditions (e.g., desertification), rapid population growth, and increasing cost of living may determine food access, availability and production in studied countries in SSA[40,41]. Governmental priorities should intensify efforts to minimize the risk of co-existence of stunting, underweight, and wasting among children under age 5 with sound socio-economic and sustainable human capital development.

Conclusions

The study investigated the socio-demographic and environmental risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The study found that the prevalence of co-existence of stunting, underweight, and wastingranged from 0.58 % in the Gambia to 12.14% in Benin. The study also found that the prevalence of co-existence of stunting, underweight, and wasting was high in Western Africa (41.78%) but low in Southern Africa (5.3%). The significant findings show that the disadvantaged have more risks of the co-existence of stunting, underweight, and wasting among under 5 children in selected SSA countries. Findings require context nutrition-specific interventions such as complementary feeding, dietary supplementation and increasing dietary diversity to promote children feeding practices across the studied countries. Besides, country-specific sustainable human capital developmental agenda (e.g., empowerment initiatives, entrepreneurial training), especially among mothers are required to help improve children's dietary intake by governments and partnering institutions or agencies.

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addition, data used are available in the public domain.

Ethics Approval and consent to participate

DHS reports ethical clearance are provided by the Ethics Committee of ORC Macro Inc. as well as Ethics Boards of partner institutions (e.g., Ministries of Health) from studied countries. The DHS procedures require that principles for the protection of respondents' anonymity and confidentiality are adhered. Inner City Fund International also guarantees that the survey protocols meet the United States Department of Health and Human Services' regulations for the respect of human subjects. The current study used a secondary data, hence, no further ethical approval was sought. The datasets are freely available for download and usage at https://dhsprogram.com/data/available-datasets.cfm.

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Data availability statement: Data are available in a public, open access repository. Data for this study were sourced from Demographic and Health surveys (DHS) and available here: http://dhsprogram.com/data/available-datasets.cfm

References

1. Amare ZY, Ahmed ME, Mehari AB. Determinants of nutritional status among children under age 5 in Ethiopia: further analysis of the 2016 Ethiopia demographic and health survey. *Global Health* 2019;15(1):1–11.
2. Anin SK, Saaka M, Fischer F, Kraemer A. Association between Infant and Young Child Feeding (IYCF) Indicators and the Nutritional Status of Children (6–23 Months) in Northern Ghana. Nutrients *2020;* 12, 2565. https://doi.org/10.3390/nu12092565
3. Madiba S, Chelule PK, Mokgatle MM. Attending informal preschools and daycare centers is a risk factor for underweight, stunting and wasting in children under the age of five years in underprivileged communities in South Africa. *International Journal of Environmental Research and Public Health* 2019; 16(14), 2589.
4. Yalew BM, Amsalu F, Bikes D. Prevalence and factors associated with stunting, underweight and wasting: a community based cross sectional study among children age 6-59 months at Lalibela Town, Northern Ethiopia. *J Nutr Disorders Ther* 2014; 4(147), 2161-0509.
5. WHO. Nutrition Landscape Information System (NLIS) Country Profile Indicators: Interpretation Guide; World Health Organization: Geneva, Switzerland, 2010.
6. Akombi BJ, Agho KE, Hall JJ, Wali N, Renzaho A, Merom D. Stunting, wasting and underweight in sub-Saharan Africa: a systematic review. *International Journal of Environmental Research and Public Health* 2017; 14(8), 863.
7. WHO. Global nutrition targets 2025: policy brief series (WHO/NMH/NHD/14.2). Geneva: World Health Organization; 2014. https://apps.who.int/iris/bitstream/handle/10665/149018/WHO_NMH_NHD_14.2_eng.pdf
8. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, Ezzati M, Grantham-McGregor S, Katz J, Martorell R, Uauy R, Maternal and Child Nutrition

Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries. *The lancet* 2013; 382(9890), 427-451.

9. World Health Organization. Levels and trends in child malnutrition: key findings of the 2019 edition (No. WHO/NMH/NHD/19.20). World Health Organization. 2019.
10. De Onis M, Onyango A, Borghi E, Siyam A, Blössner M, Lutter C. Worldwide implementation of the WHO child growth standards. *Public Health Nutrition* 2012; 15(9), 1603-1610.
11. De Onis M, Blössner M, Borghi E. Prevalence and trends of stunting among pre-school children, 1990–2020. *Public Health Nutrition* 2012; 15(1), 142-148.
12. World Health Organization. Community-based management of severe acute malnutrition: a joint statement by the World Health Organization, the World Food Programme, the United Nations System Standing Committee on Nutrition and the United Nations Children's Fund. 2007.
13. UNICEF. Levels and trends in child malnutrition, United Nations Children's fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and trends in child malnutrition: key findings of the 2019 edition of the joint child malnutrition estimates. Geneva: World Health Organization; 2019 Licence: CC BY-NC-SA 3.0 IGO; 2019.
14. Central Statistical Agency (CSA)[Ethiopia] and ICF. Ethiopia demographic and health survey, Addis Ababa, Ethiopia and Calverton, Maryland, USA. 2016.
15. Yaya S, Uthman OA, Ekholuenetale M, Bishwajit G, Adjiwanou V. Effects of birth spacing on adverse childhood health outcomes: evidence from 34 countries in sub-Saharan Africa. *J Matern & Neonatal Med* 2020;33(20):3501–8.
16. Armah FA, Ekumah B, Yawson DO, Odoi JO, Afitiri A, Nyieku FE, et al. Predictive Probabilities of Access to Clean Cooking: Evidence from the Demographic and Health Surveys in 31 Countries in Sub-Saharan Africa. 2019;12(3):320–2.
17. Mamabolo RL, Alberts M, Steyn NP, Delemarre-van de Waal HA, Levitt NS. Prevalence and determinants of stunting and overweight in 3-year-old black South African children residing in the Central Region of Limpopo Province, South Africa. *Public Health Nutrition* 2005; 8(5), 501-508.
18. Novignon J, Aboagye E, Agyemang OS, Aryeetey G. Socioeconomic-related inequalities in child malnutrition: evidence from the Ghana multiple indicator cluster survey. *Health Economics Review* 2015; 5(1), 1-11.
19. Khara T, Mwangome M, Ngari M, Dolan C. Children concurrently wasted and stunted: A meta-analysis of prevalence data of children 6–59 months from 84 countries. Maternal & child nutrition. 2018 Apr;14(2):e12516.
20. Boah M, Azupogo F, Amporfro DA, Abada LA. The epidemiology of undernutrition and its determinants in children under five years in Ghana. Plos one. 2019 Jul 31;14(7):e0219665.
21. Khan RE, Raza MA. Determinants of malnutrition in Indian children: new evidence from IDHS through CIAF. Quality & Quantity. 2016 Jan 1;50(1):299-316.
22. Angood C, Khara T, Dolan C, Berkley JA, WaSt Technical Interest Group. Research priorities on the relationship between wasting and stunting. PloS one. 2016 May 9;11(5):e0153221.

23. Corsi DJ, Neuman M, Finlay JE, Subramanian SV. Demographic and health surveys: a profile. *International Journal of Epidemiology* 2012; 41(6), 1602-1613.
24. Aliaga A, Ruilin R. Cluster optimal sample size for demographic and health surveys. In 7th International Conference on Teaching Statistics–ICOTS (Vol. 7, pp. 2-7). 2006.
25. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, Strobe Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. International journal of surgery. 2014; 12(12), 1495-1499.
26. Collins J, Ward BM, Snow P, Kippen S, Judd F. Compositional, Contextual, and Collective Community Factors in Mental Health and Well-Being in Australian Rural Communities. *Qualitative Health Research* 2017; 27(5), 677–687. https://doi.org/10.1177/1049732315625195
27. Pol LG, Thomas RK. The demography of health and health care. Springer Science & Business Media. 2001.
28. Armah FA, Ekumah B, Yawson DO, Odoi JO, Afitiri AR, Nyieku F.E. Access to improved water and sanitation in sub-Saharan Africa in a quarter century. *Heliyon* 2018; 4(11), e00931. https://doi.org/10.1016/j.heliyon.2018.e00931
29. Ross CE, Mirowsky J. Neighborhood socioeconomic status and health: context or composition? *City & Community* 2008; 7(2), 163–179.
30. Amegah AK, Boachie J, Näyhä S, Jaakkola JJK. Association of biomass fuel use with reduced body weight of adult Ghanaian women. *J Expo Sci Environ Epidemiol* 2019;1.
31. Alemayehu M, Tinsae F, Haileslassie K, Seid O, Gebregziabher G, Yebyo H. Undernutrition status and associated factors in under-5 children, in Tigray, Northern Ethiopia. *Nutrition* 2015; 31(7-8), 964-970.
32. Mya KS, Kyaw AT, Tun T. Feeding practices and nutritional status of children age 6-23 months in Myanmar: A secondary analysis of the 2015-16 Demographic and Health Survey. *PloS one* 2019; 14(1), e0209044.
33. Bork KA, Diallo A. Boys are more stunted than girls from early infancy to 3 years of age in rural Senegal. *The Journal of Nutrition* 2017; 147(5), 940-947.
34. Tumilowicz A, Habicht JP, Pelto G, Pelletier DL. Gender perceptions predict sex differences in growth patterns of indigenous Guatemalan infants and young children. *The American Journal of Clinical Nutrition* 2015; 102(5), 1249-1258.
35. Mukabutera A, Thomson DR, Hedt-Gauthier BL, Basinga P, Nyirazinyoye L, Murray M. Risk factors associated with underweight status in children under five: an analysis of the 2010 Rwanda Demographic Health Survey (RDHS). *BMC Nutrition* 2016; 2(1), 1-12.
36. Oyekale AS. Factors explaining acute malnutrition among under-five children in Sub-Sahara Africa (SSA). *Life Sci J* 2012; 9, 2101-7.
37. Keats A. Women's schooling, fertility, and child health outcomes: Evidence from Uganda's free primary education program. *Journal of Development Economics* 2018; 135, 142-159.
38. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Poor nutrition status and associated feeding practices among HIV-positive children in a food secure region in Tanzania: a call for tailored nutrition training. *PloS one* 2014; 9(5), e98308.
39. Iannotti LL, Dulience SJL, Green J, Joseph S, François J, Antenor ML, ... Nickerson NM. Linear growth increased in young children in an urban slum of Haiti: a

randomized controlled trial of a lipid-based nutrient supplement. *The American Journal of Clinical Nutrition* 2014; 99(1), 198-208.

40. Lopriore C, Muehlhoff E. Food security and nutrition trends in West Africa—Challenges and the way forward. In Proceedings of the 2nd International Workshop on Food-based Approaches for a Healthy Nutrition, Ouagadougou, Burkina. 2003; 23–28.
41. Salami A, Kamara AB, Brixiova Z. Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities; African Development Bank: Tunis, Tunisia, 2010.

Figures

Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

Tables

Table 1: Distribution of socio-demographic, environmental and contextual variables

Variable	%	Variable	%
Socio-demographic factors			
Age of child		Urbanicity	
0	30.87	Urban	33.21
1	28.42	Rural	66.79
2	20.22	Place of delivery	
3	12.40	Home	31.33
4	8.09	Health facility	67.51
Sex of child		Other	1.16
Male	50.47	Wealth status	
Female	49.53	Poor	42.41
Birth order		Middle	20.28
1	19.52	Rich	37.31
2 to 4	48.09	Age of household head	
5 and above	32.39	Young-adults	43.08
Perceived size at birth		Middle-aged adults	43.76
Large	33.71	Old-aged adults	13.16
Average	49.74	Sex of household head	
Small	16.54	Male	79.77
Mother's characteristics		Female	20.23
Maternal age		Access to electricity	
15-19	7.13	No	69.20
20-49	92.87	Yes	30.80
Educational attainment		**Environmental factors**	
No education	41.82	Type of toilet facility	

Primary	31.26	Improved	42.47
Secondary	23.82	Unimproved	57.53
		Source of drinking	
Higher	3.10	water	
Working status		Improved	65.63
No	35.49	Unimproved	34.37
Yes	64.51	Type of cooking fuel	
Antenatal visits during pregnancy		Clean	89.76
No	10.76	Unclean	10.24
Yes	89.24	Geographic region	
Postnatal check within 2 months		Western	41.78
No	58.49	Eastern	32.84
Yes	41.51	Central	20.08
Access to media (tv/radio/newspaper)		South Africa	5.30
Yes	35.33		
No	64.67		(N=127,487)

Distribution by country is shown in appendix 1

Table 2: Prevalence (%) of co-existence of wasting, stunting and underweight and its associated socio-demographic and environmental factors

Variable	Co-existed (weighted %)	95% CI	Chi²	Variable	Co-existed (weighted %)	95% CI	Chi²
Socio-demographic factors				**Access to media (tv/radio/newspaper)**			p<0.001
Age of child			p<0.001	Yes	2.14	2.0-2.2	
						3.6-	
0	1.75	1.6-1.9		No	3.78	4.0	
1	4.44	4.2-4.7		**Urbanicity**			p<0.001
2	3.01	2.8-3.2		Urban	1.73	1.6-1.9	
3	1.62	1.4-1.8		Rural	3.21	3.1-3.3	

4	1.33	1.1-1.6		**Country**			p<0.001
Sex of child			p<0.001	Angola	2.46	2.1-2.8	
Male	3.43	3.3-3.6		Benin	2.04	1.8-2.2	
Female	1.99	1.9-2.1		Burkina Faso	5.31	4.9-5.8	
Birth order			p<0.001	Burundi	3.76	3.2-4.4	
1	2.25	2.1-2.4		Cameroon	1.27	0.9-1.7	
2 to 4	2.56	2.4-2.7		Chad	5.86	5.2-6.5	
5 and above	3.23	3.1-3.4		Comoros	1.98	1.3-2.9	
Perceived size at birth			p<0.001	Congo	0.98	0.7-1.5	
Large	1.78	1.7-1.9		Cote d'Ivoire	2.28	1.7-3.0	
Average	2.6	2.5-2.7		DR Congo	2.66	2.2-3.2	
Small	4.98	4.7-5.3		Ethiopia	3.64	3.2-4.1	
Mother's characteristics				Gabon	0.63	0.3-1.0	
Maternal age			P = 0.080	Gambia	3.61	2.4-5.2	
15-19	2.78	2.5-3.1		Ghana	1.37	0.9-2.0	
20-49	2.71	2.6-2.8		Guinea	2.26	1.7-2.9	
Educational attainment			p<0.001	Kenya	0.94	0.7-1.2	
No education	4.19	4.0-4.4		Lesotho	0.86	0.7-1.0	
Primary	2.09	2.0-2.2		Liberia	2.37	1.7-3.1	
Secondary	1.22	1.1-1.3		Malawi	1.03	0.7-1.4	
Higher	0.66	0.4-1.0		Mali	3.62	2.5-4.1	
Working status			p<0.001	Namibia	1.99	1.2-3.1	
No	3.13	3.0-3.3		Nigeria	4.1	3.7-4.6	

Yes	2.48	2.4-2.6		Rwanda	6.17	5.5-6.9	
Antenatal visits during pregnancy			p<0.001	Senegal	2.43	1.8-3.2	
No	5.41	5.0-5.8		Sierra Leone	1.94	1.4-2.5	
						0.02-	
Yes	2.39	2.3-2.5		South Africa	0.18	0.8	
Postnatal check within 2 months			p<0.001	Tanzania	1.86	2.1-3.5	
No	2.93	2.8-3.1		Togo	2.72	2.1-3.4	
Yes	2.42	2.3-2.6		Uganda	1.2	0.8-1.7	
Place of delivery			p<0.001	Zambia	1.22	1.0-1.5	
Home	4.36	4.2-4.6		Zimbabwe	0.78	0.5-1.1	
Health facility	1.96	1.9-2.1		**Environmental factors**			
				Type of toilet			
Other	2.45	1.7-3.3		**facility**			p<0.001
Wealth status			p<0.001	Improved	1.76	1.6-1.9	
Poor	3.46	3.3-3.6		Unimproved	3.43	3.3-3.6	
Middle	2.74	2.5-2.9		**Source of drinking water**			p<0.001
Rich	1.86	1.7-2.0		Improved	2.54	2.4-2.6	
Age of household			p =				
head			0.276	Unimproved	3.06	2.9-3.2	
				Type of cooking			
Young-adults	2.65	2.5-2.8		**fuel**			p<0.001
						0.8.2-	
Middle-aged adults	2.76	2.6-2.9		Clean	0.98	1.2	
Old-aged adults	2.8	2.6-3.1		Unclean	2.92	2.8-3.0	
Sex of household				**Geographic**			
head			p<0.001	**region**			p<0.001
Male	2.82	2.7-2.9		Western	3.11	3.0-2.3	
Female	2.33	2.1-2.5		Eastern	2.43	2.3-2.6	

Access to electricity			p<0.001	Central	2.87	2.7-3.1
No	3.21	3.1-3.3		South Africa	0.88	0.66-1.1
Yes	1.61	1.5-1.7				

Table 3: Multinomial regression showing risk factors of co-existence of stunting, underweight, and wasting

Variable	Base outcome (Ref: Normal)					
	Single and two dimensions			Co-existence of three-dimensions		
	RRR	95% CI		RRR	95% CI	
Age of child (Ref:0)						
1	2.008***	1.93	2.089	3.714***	3.319	4.156
2	2.624***	2.514	2.739	2.827***	2.48	3.222
3	2.122***	2.018	2.231	1.464***	1.227	1.748
4	1.504***	1.417	1.597	1.051	0.84	1.315
Sex of child (Ref: Male)						
Female	0.752***	0.731	0.775	0.468***	0.429	0.51
Birth order (Ref: 1)						
2	0.938**	0.896	0.981	1.002	0.875	1.146
5 and above	0.969	0.92	1.021	0.995	0.858	1.155
Perceived size at birth (Ref: Large)						
Average	1.32***	1.276	1.365	1.756***	1.574	1.958
Small	1.931***	1.846	2.02	3.818***	3.383	4.308
Maternal age (Ref: 15-19)						
20-49	0.834***	0.78	0.891	0.881	0.735	1.056
Educational attainment (Ref: Higher)						
No education	2.624***	2.305	2.987	3.291***	1.961	5.522
Primary	2.189***	1.927	2.487	2.381***	1.417	4.001

Secondary	1.751***	1.545	1.985	1.617	0.971	2.691
Working status (Ref: Yes)						
No	1.018	0.984	1.053	1.195***	1.086	1.314
Antenatal visits during pregnancy (Ref: Yes)						<0.001
No	1.139***	1.079	1.201	1.364***	1.208	1.541
Postnatal check within 2 months (Ref: Yes)						
No	0.98	0.946	1.015	0.977	0.879	1.086
Place of delivery (Ref: Health facility)						
Home	1.183***	1.137	1.23	1.372***	1.232	1.529
Other	1.046	0.912	1.201	1.047	0.71	1.543
Wealth status (Ref: Rich)						
Poor	1.297***	1.235	1.361	1.408***	1.235	1.605
Middle	1.195***	1.138	1.254	1.214**	1.054	1.397
Age of household head (Ref: Young-adult)						
Middle-aged adults	0.954**	0.921	0.987	1.01	0.913	1.118
Old-aged adults	0.974	0.93	1.021	1.065	0.936	1.213
Sex of household head (Ref: Male)						
Female	0.977	0.94	1.015	1.035	0.925	1.159
Access to media (tv/radio/newspaper) (Ref: Yes)						
No	1.079***	1.042	1.117	1.255***	1.144	1.377
Access to electricity (Ref: Yes)						
No	1.136***	1.083	1.191	1.062	0.922	1.225
Type of toilet facility (Ref: Improved)						
Unimproved	1.027	0.991	1.065	1.158**	1.032	1.3
Source of drinking water (Ref: Improved)						
Unimproved	0.959**	0.928	0.99	0.968	0.885	1.058
Type of cooking fuel (Ref: Clean)						
Unclean	1.177***	1.089	1.271	1.316	0.97	1.787
Urbanicity (Ref: Urban)						
Rural	1.05**	1.006	1.095	0.943	0.832	1.069

Country-level risk of co-existence of stunting, underweight and wasting, were also estimated (see appendix 2)

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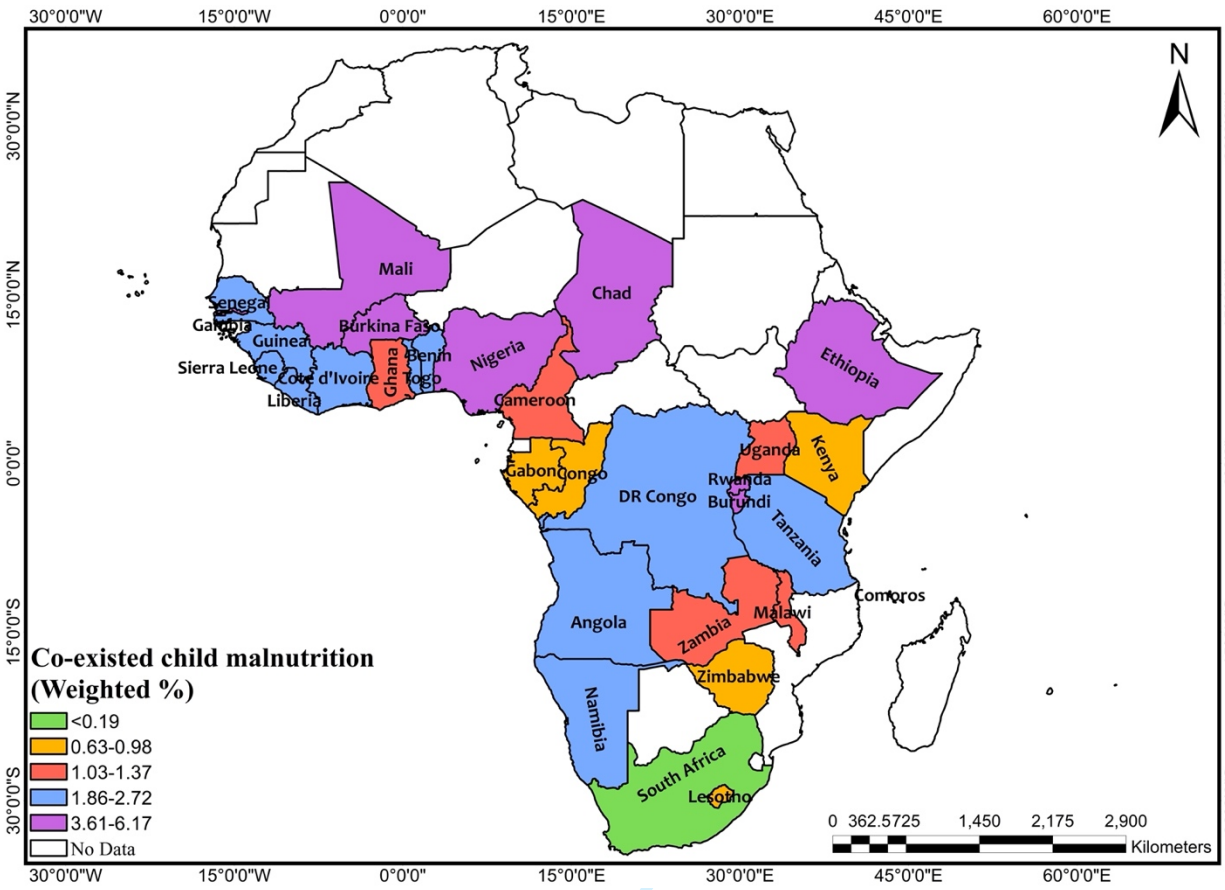

Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

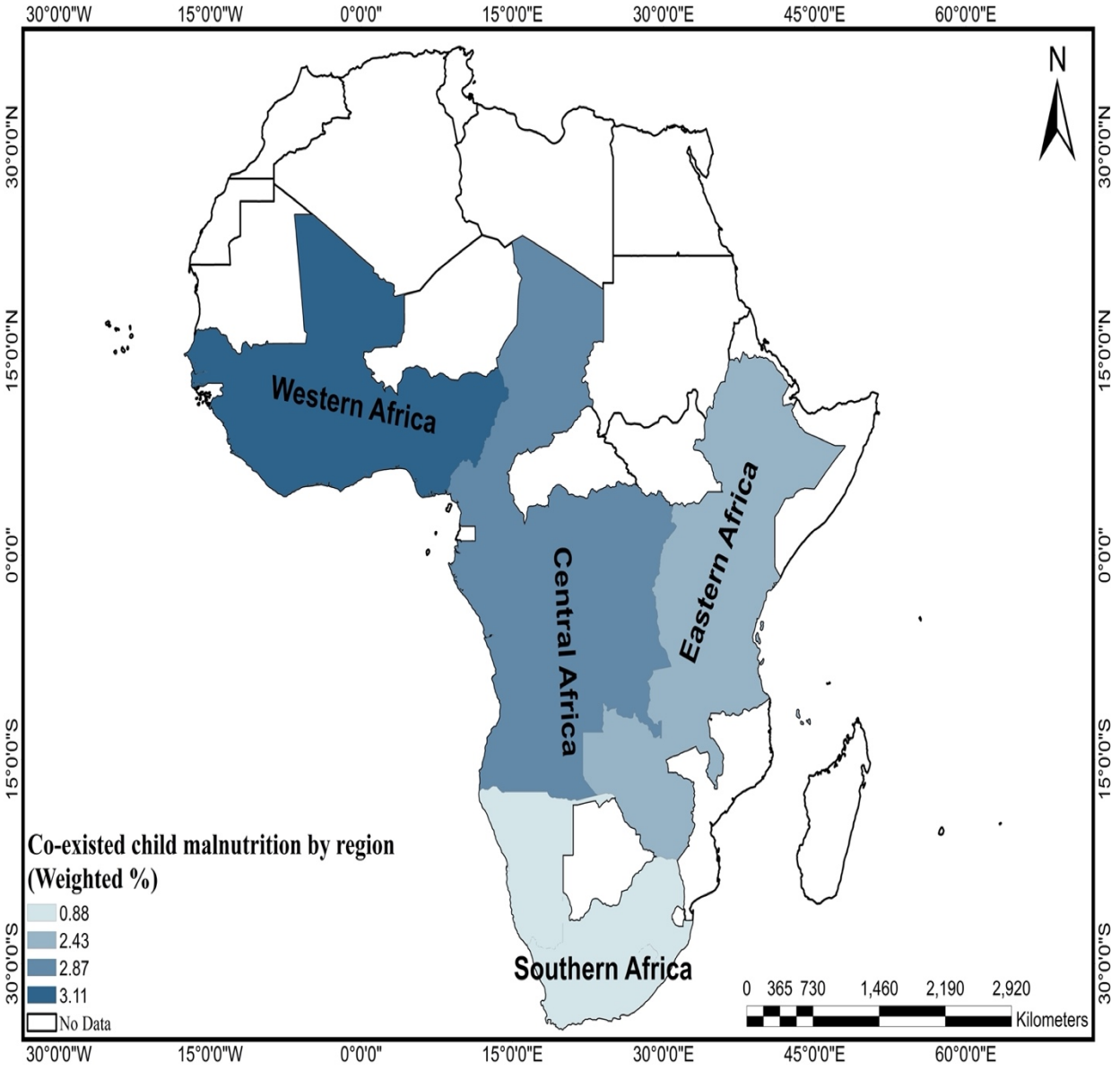

Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

Supplementary Tables

Appendix 1: Distribution of sample by country

Country	Survey year	n	%
Angola	2015-16	7,318	5.74
Benin	2017-18	15,473	12.14
Burkina Faso	2010	8,908	6.99
Burundi	2016-17	4,172	3.27
Cameroon	2018	2,911	2.28
Chad	2014-2015	5,999	4.71
Comoros	2012	1,320	1.03
Congo	2013	2,609	2.05
Cote d'Ivoire	2011-12	2,174	1.71
Congo DR	2013-14	4,806	3.77
Ethiopia	2016	6,573	5.16
Gabon	2012	1,960	1.54
Gambia	2013	743	0.58
Ghana	2014	1,896	1.49
Guinea	2018	2,237	1.75
Kenya	2014	6,066	4.76
Lesotho	2014	1,012	0.79
Liberia	2013	1,946	1.53
Malawi	2015-16	4,027	3.16
Mali	2018	5,653	4.43
Namibia	2013	905	0.71
Nigeria	2018	7,379	5.79
Rwanda	2014-15	4,408	3.46
Senegal	2010-11	1,944	1.52
Sierra Leone	2019	2,689	2.11
South Africa	2016	855	0.67
Tanzania	2015-16	6,061	4.75
Togo	2013-14	2,220	1.74
Uganda	2016	2,891	2.27
Zambia	2018	6,347	4.98
Zimbabwe	2015	3,987	3.13

Appendix 2: Multicollinearity diagnosis				
Variable	VIF	SQRT VIF	Tolerance	R-Squared
Age of child	1.05	1.02	0.9547	0.0453
Sex of child	1.01	1	0.9948	0.0052
Birth order	1.36	1.17	0.7366	0.2634
Perceived size at birth	1.02	1.01	0.9798	0.0202
Age at child birth	1.22	1.1	0.8224	0.1776
Educational attainment	1.51	1.23	0.664	0.336
Working status	1.07	1.03	0.9357	0.0643
Antenatal visits during pregnancy	1.25	1.12	0.7976	0.2024
Postnatal check within 2 months	1.1	1.05	0.9098	0.0902
Place of delivery	1.31	1.15	0.7617	0.2383
Wealth status	1.8	1.34	0.5554	0.4446
Age of household head	1.05	1.02	0.9546	0.0454
Sex of household head	1.03	1.02	0.9702	0.0298
Access to media (tv/radio/newspaper)	1.26	1.12	0.7913	0.2087
Access to electricity	1.71	1.31	0.5837	0.4163
Type of toilet facility	1.35	1.16	0.7404	0.2596
Source of drinking water	1.09	1.04	0.9191	0.0809
Type of cooking fuel	1.31	1.14	0.7653	0.2347
Urbanicity	1.58	1.26	0.6319	0.3681
Country	1.17	1.08	0.8579	0.1421
Mean VIF	1.26			

Appendix 3: **Country-level risk of co-existence of stunting, wasting, and underweight**

	Base outcome (Ref: Normal)					
	Single and two dimensions			Co-existence of three-dimensions		
	RRR	95% CI		RRR	95% CI	
Country (Ref: Angola)						
Benin	0.651***	0.598	0.708	0.625***	0.489	0.798
Burkina Faso	0.952	0.866	1.046	1.946***	1.526	2.481
Burundi	1.580***	1.424	1.753	2.049***	1.545	2.718
Cameroon	0.669***	0.593	0.756	0.398***	0.261	0.609
Chad	0.910	0.823	1.007	1.505**	1.184	1.913
Comoros	0.883	0.745	1.046	0.656	0.378	1.138
Congo	0.674***	0.580	0.783	0.472**	0.279	0.800
Cote d'Ivoire	0.734***	0.638	0.844	0.739	0.492	1.109
DR Congo	1.229***	1.100	1.373	1.351	0.988	1.847
Ethiopia	0.810***	0.726	0.904	0.813	0.604	1.095
Gabon	0.495***	0.415	0.59	0.319**	0.128	0.796
Gambia	0.732**	0.603	0.889	1.001	0.618	1.620
Ghana	0.453***	0.386	0.531	0.545**	0.346	0.857
Guinea	0.798***	0.705	0.904	0.726	0.509	1.036
Kenya	0.553***	0.498	0.615	0.321***	0.230	0.449
Lesotho	0.777**	0.654	0.924	0.369***	0.177	0.772
Liberia	0.658***	0.565	0.768	0.776	0.484	1.243
Malawi	0.794***	0.708	0.889	0.447***	0.291	0.687
Mali	0.600***	0.541	0.664	1.006	0.769	1.316
Namibia	0.680***	0.568	0.815	0.849	0.505	1.426
Nigeria	0.953	0.868	1.046	1.527**	1.183	1.972
Rwanda	1.059	0.954	1.176	1.991***	1.541	2.571
Senegal	0.660***	0.572	0.761	0.643*	0.434	0.952
Sierra Leone	0.641***	0.567	0.725	0.656*	0.447	0.963
South Africa	0.788*	0.634	0.979	0.108***	0.033	0.352
Tanzania	0.772***	0.699	0.851	0.699**	0.512	0.954
Togo	0.557***	0.490	0.633	0.838	0.590	1.190
Uganda	0.627***	0.556	0.708	0.421***	0.278	0.637
Zambia	0.904*	0.818	0.998	0.519***	0.366	0.736
Zimbabwe	0.693***	0.620	0.775	0.344***	0.214	0.554

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Risk factors associated with the co-existence of stunting, underweight, and wasting in children under five: Analysis of cross-sectional surveys from 31 sub-Saharan African countries

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ABSTRACT

Objective: This study investigated the risk factors associated with the co-existence of stunting, underweight, and wasting among children under age five in sub-Saharan Africa(SSA).

Methods: Data from 31 sub-Saharan African countries were pooled from the Demographic and Health Surveys collected between 2010 and 2019. We examined the risk of co-existence of undernutrition using multinomial logistic regression models, with results presented as relative risk ratios with their respective confidence intervals.

Outcome measures: The outcome variables were three child anthropometrics: stunting (height-for-age z-scores); underweight (weight-for-age z-scores); and wasting (weight-for-height z-scores).

Results: The prevalence of co-existence of stunting, underweight, and wasting varied across countries and sub-regions, with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting as Benin (12.14%) and Gambia (0.58%) respectively. The risk of co-existence of the three undernutrition dimensions was higher among children age 1 year compared to those aged 0. The risk of co-existence of the three dimensions was higher among female children, those with small size at birth, those whose mothers had no education, not working, had no antenatal visits during pregnancy, children delivered at home, those whose mothers were poor, had no access to media and children whose mothers had unimproved toilet facility.

Conclusion: Findings suggest the urgent need for consideration of the co-existence of stunting, wasting and underweight among under-five children in policy design and programming of interventions to eradicate child malnutrition in SSA. In the short-term, national-level policies and interventions need to be well-tailored considering the compositional characteristics. In the long-term, regional policies and coordinated interventions among governments of SSA countries need to be designed to address the disparate prevalence of the co-existence of stunting, wasting and underweight in under-five children across the four geographic regions.

Keywords: co-existence; stunting; underweight; wasting; children under five; sub-Saharan Africa

Strength and Limitations

- The use of nationally representative data ensures that our findings are generalizable and replicable in the 31 SSA countries included in this study.
- Findings contribute to bridging the gaps identified in the current research on CNS by including multiple indicators (stunting, underweight, and wasting) in the concurrent measurement of our outcome variable, compared to the unitary assessment on undernutrition that currently dominates literature.
- The study relied on secondary data, the analysis was limited to only variables that were in the dataset. Hence, interpretations and inferences made from current findings must be limited to only these observed variables.
- Also, the DHS employs cross-sectional designs which restrict causality on the noted outcomes.
- The key variables were self-reported by the mothers, and therefore, there is the likelihood of recall bias and other social desirability concerns in the present study.

BACKGROUND

Undernutrition among children under 5 years remains a major public health problem across many low-and middle-income countries[1-3]. Factors such as insufficient food intake, diarrhoea, recurring infections, poor sanitation practices, and low parental education have been identified as significant contributors to the high prevalence of undernutrition during childhood[1,4,5]. Despite the numerous interventions rolled out to address childhood undernutrition especially in sub-Saharan Africa where the phenomenon is quite pervasive, the progress seems to be insignificant[6,7]. For example, a study reported that child undernutrition accounted for nearly half (45%) of the child mortality rate in low-and middle-income countries[8]. Aside from that, it was reported in 2018 that about 149 million and 49 million children under age 5 were stunted and wasted respectively[9].

Three main indicators that are often used to represent undernutrition are underweight or low weight for age, stunting or low height for age, and wasting or low weight for height[2,10-12]. Among the three indicators of undernutrition, stunting has been identified as the problem with the greatest magnitude among under 5 children in developing countries[2,3]. Even though the prevalence of stunting in sub-Saharan Africa is declining, it is worth noting that it is still above 30%[13] which is undeniably high. Research also indicates that the country-specific prevalence of stunting, underweight and wasting is still high[2,3]. For instance, in Ethiopia, the prevalence of wasting and stunting were 10% and 38% respectively[14]. Additionally, the prevalence of stunting, underweight and wasting among children in South Africa were 35.8%, 20.5%, and 17.2%[3]. Likewise, Anin et al.[2] reported 33.2%, 14.1%, 27% and 2.6% of prevalence in stunting, wasting, underweight and overweight among infants (6-23 months) across Northern Ghana.

Previous studies have investigated the compositional and contextual risk factors associated with either stunting, underweight or wasting among children under 5 years and found the age of a child, sex of the child, child's size at birth, mother's age during childbirth, mother's educational level, birth order, place of residence and mother's body mass index (BMI) as associated factors[1-3,15,16]. Other studies also found a significant linkage between household wealth quintile and maternal short stature, and nutritional status of children under 5[17,18]. Regarding the sex of a child, for example, female children were found to be less likely to suffer from stunting compared to males[1,3].

Apart from studies that have examined the factors associated with either stunting, underweight, and wasting, some scholars have begun looking at predictors of the co-existence of any two or three of the indicators of malnutrition. A study in 84 countries that examined the prevalence and predictors of co-existence of stunting and wasting found sex and age of children as significant predictors[19]. Other studies in Ghana[20] and India[21] also examined the co-existence of stunting, underweight, and wasting and found birth interval, birth weight, dietary diversity, place of delivery, wealth index, mother's BMI, mother's educational level, and partners' educational level as associated factors. The need to examine the co-existence of stunting, underweight and wasting is important because not much work has been done on that subject and hence children who concurrently suffer from stunting, underweight, and wasting are less likely to be reached in malnutrition prevention programmes, especially in SSA. For instance, some scholars have indicated that despite evidence that wasting and stunting are global public health problems that frequently co-exist, they are usually separated in terms of policy, guidance, programming

and financing[22]. This creates a gap in the literature that needs to be filled. Despite the detrimental consequences of undernutrition on the health and wellbeing of children under 5 in SSA, studies utilizing current, and nationally representative data to investigate the risk factors associated with the co-existence of stunting, underweight, and wasting among this age group are absent in the literature. Studies presenting empirical analyses of the co-existence of these three indicators of child undernutritionin SSA are absent in extant literature making it difficult for policymakers and nutritional experts to provide up-to-date trends with appropriate strategies to curb the situation in the sub-region. This research lag presents a void in extant literature which this study seeks to bridge. Therefore, the study investigated the risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from the Demographic Health Survey (DHS) conducted in 31 countries between 2010 and 2019. The findings of the study could contribute to the formulation of policies and interventions to respond to the nutritional needs of children under 5 years and also suggest pragmatic ways of reducing undernutrition among children in the sub-region.

METHODS

Data Source

The dataset included 127,487 children under the age of 5 years from 31 sub-Saharan African countries (Figure 1) were pooled from the most current Demographic and Health Surveys (DHS) conducted between 2010 and 2019 (Appendix 1). Specifically, the data were pooled from the children's files in each of the countries. The DHS Program has conducted over 400 surveys in over 90 developing countries around the world since 1984 every five years[23]. The program implements cross-sectional surveys to gather nationally-representative data, analyze and disseminate accurate information on important demographic and health indicators spanning population, nutrition, and diseases. For all surveys, standardized protocols designed for each target group including children, women, and men at the household level are employed to allow for cross-national comparisons. Stratified two-stage sampling involving first, the listing of enumeration areas and selection of clusters, and then a random selection of households in each cluster. The detailed sampling method can be found in a previous study[24]. The dataset is freely available for download at: https://dhsprogram.com/data/available-datasets.cfm[25]. The Strengthening Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed in writing the manuscript[26].

Study Variables

Outcome Variable

The outcome variable considered in this study is derived from three child anthropometric variables including stunting (height-for-age z-scores); underweight (weight-for-age z-scores) and wasting (weight-for-height z-scores). The DHS (2021) specifies categorization for each of these variables following the WHO child growth standard. Each of the three variables we coded into "0" for "Normal" and "1" for "Stunting", "underweight" and "Wasting" respectively.

These three variables were then added to generate the outcome variable "Co-existed undernutrition" with scores (discrete) ranging from 0 to 3 where 0 implies "Normal", that is, children with none of the three conditions; 1 implies "Single burden", that is, the child suffers from one of the three conditions; 2 indicates that child suffers from "Two burdens" out of the three; and 3 shows "Co-existed", that is, the child suffers from all three conditions of undernutrition. For parsimony, children who suffered from "Single burden" and those who suffered from "Two burdens" were added resulting in the variable "Co-existed undernutrition" with three response categories: 0=Normal; 1=One or two burdens; and 3=co-existed.

Independent Variables

Several risk factors spanning compositional to contextual factors have been associated with child undernutrition. The relevant biosocial characteristics and sociocultural factors related to the child, mother, household head and the household together form compositional factors[27,28]. Factors that describe location or "place-based" variables are contextual factors[20,27,29,30]. The relevant compositional factors considered include the age of the child; sex of the child; birth order of child; perceived size at birth; mother's age; educational attainment; working status; antenatal visits during pregnancy; postnatal check within 2 months; and place of delivery. At the household level, relevant variables included are the wealth status; the age of household head; sex of household head (male and female); access to electricity; and access to media which was derived from the three variables "access to television", "radio" and "newspaper". Household basic needs including the type of toilet facility (re-coded into "improved" and unimproved"[29]; source of drinking water (re-coded as "improved" and "unimproved"[29], and type of household cooking fuel (re-coded into "clean" and "unclean" [29,31] are also considered. The contextual factors considered are urbanicity and the country of origin of the participant.

Data Analyses

The statistical analysis of the data was performed using the Stata SE software version 14.2. The "svyset" command was first used to declare the data as survey data to prevent the potential effects of the complex sampling techniques on the analyses. The sample weight variable in the DHS was used to provide weighted samples in the analyses. To understand the distributions of the variables, the data were summarized and presented in tables using descriptive statistics (frequencies, weighted percentages, and 95% confidence intervals (CIs) of percentages). We further integrated the data into a GIS environment and presented the distribution of key variables across the study countries and geographic regions in map images (Figure 1 and Figure 2). This approach enhances the visualization of the data and understanding of the context of the study. The associations between the co-existence of undernutrition and each of the risk factors considered were assessed using the chi-square test of independence, with results presented in a contingency table. The risk factors as independent variables were then subjected to collinearity diagnosis tests, including Variance Inflation Factors (VIF), Square VIF, Tolerance, and R-squared. This was done to ascertain whether the independent variables were actually "independent", that is, are not correlated with one another and will not share variance in the outcome variable. Results from the multicollinearity diagnoses test (See Appendix 2) show that the variables were not correlated (Mean VIF=1.26; Maximum VIF=1.71; Minimum VIF=1.02). To determine

the risk factors associated with the co-existence of undernutrition, a multinomial regression model was implemented. All statistical tests were conducted at $p<0.05$.

Ethical Approval

This study used secondary data from the DHS Program. Since we neither interacted directly nor indirectly with the study participants, there was no need for ethical approval. Details on the ethical considerations of the DHS Program could be found at https://dhsprogram.com/methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm.

Patient and public involvement

Patients and the public were not involved in the design and conduct of this research

Results

Distribution of sample characteristics

The study included a total of 127,487 under-five children. It is found that most (30.87%) of the children were less than a year (Table 1). With regards to sex, both males and females constituted approximately half of the sample. A majority of the children (92.87%) were born to mothers aged between 20 to 49years while only 7.13% were born to mothers aged 15 to 19years. In terms of education, most (41.82%) of the children were born to mothers with no formal education. Only 3.10% of the children were born to a mother with a higher level of educational attainment. Further, 42.1% of the children were born in poor households while 37.21% were born in rich households. More than half (57.53%) of the children lived in a household with unimproved toilet facilities. However, most (65.63%) of the children lived in households with access to improved drinking water sources. Similarly, a majority (89.76%) of the children lived in households using clean cooking fuel (Table 1).

As shown in Appendix 2, the prevalence of co-existence of stunting, underweight, and underweight varied across countries and sub-regions, with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting as Rwanda (6.17%) and South Africa (0.18%) respectively (Figure 1). In terms of sub-region, the highest prevalence of co-existence of stunting, underweight, and wasting was observed in Western Africa (3.11%) and the lowest prevalence in Southern Africa (0.88%) (Figure 2).

Significant associations between all the independent variables and co-existence of stunting, wasting, and underweight, except maternal age and age of household head, were identified (Table 2).

Table 1

Figure 1

Figure 2

Table 2

Risk factors of the co-existence of stunting, wasting and underweight

Table 3 shows the results of the multinomial regression analysis of the risk factors of co-existence of dimensions of undernutrition (stunting, underweight, and wasting) among

children under five years in the SSA. Age of child, size of the child at birth, sex of the child, birth order, educational level, maternal age, ANC attendance, place of delivery, source of drinking water, sex of household head, wealth index, access to electricity and place of residence were associated with one or two dimensions of undernutrition. See Appendix 3 for country-level risk of co-existence of stunting, wasting, and underweight.

Regarding the co-existence of the three dimensions of undernutrition (stunting, underweight, and wasting), age of the child, sex of the child, perceived birth size, maternal educational attainment, working status, antenatal visits during pregnancy, place of delivery, wealth status, access to media, and type of toilet facility were found to be significant risk factors (Table 3).

Table 3

DISCUSSION

The study investigated the risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The study found that the countries with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting were Benin and Gambia respectively. In terms of geographic region, the highest prevalence of co-existence of stunting, underweight, and wasting was observed in Western Africa and the lowest prevalence in Southern Africa. The disparities in the prevalence among the countries and geographical regions could be attributed to the nutritional practices and beliefs practised in the countries and geographical regions. Differences in the health policies provided by governments in the various countries could also account for the disparities noted. This finding implies that countries that have high prevalence should take critical lessons from the countries that are doing well regarding the implementation of nutritional policies and interventions (e.g., increasing dietary supplementation, increasing dietary diversity) that target the reduction of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa[2].

Similar to previous studies[1,3], this study found that children aged 1 year, 2 years, and 3 years were at greater risk of having co-existence of all the three forms of undernutrition compared to those aged 0. A plausible reason for this finding could be that as children grow their energy needs also increase[1], increasing their risk of having all three nutritional conditions. Alternatively, since these nutritional conditions may manifest after long durations of improper nutritional practices or undernutrition[1,3], older children may be at higher risk of having all three nutritional conditions. The finding suggests that complementary foods given to children as they grow are inadequate. To reduce the risk of co-existence of stunting, underweight, and wasting among under 5 children, the health sectors in the various countries should invest heavily in providing adequate complementary feeding to this category of children.

Corroborating the findings of other studies[1,3,32,33], this study also found that children who were females were less likely to have a co-existence of the three dimensions of undernutrition compared to their male counterparts. An acceptable explanation for this finding could be the biological variations in morbidity between males and females at that young age[3]. It is also possible that since male children have higher birth weight compared to females, they require more energy[1,34], which increases the risk of males having all three

nutritional conditions. Moreover, male children are perceived to be hungrier than females, therefore breastfeeding alone could be insufficient or inadequate[3,35], increasing their susceptibility to having the three nutritional conditions. The finding suggests that male children should be given critical attention in the development and implementation of nutritional programs (e.g., dietary supplementation) to mitigate the co-existence of stunting, underweight, and wasting among these male children under 5 years.

The study found that the risk of co-existence of the three dimensions of undernutrition was higher among children with the average size at birth and small size at birth compared to children with large size at birth. It has been proven that undernutrition in children is partly influenced by maternal nutrition practices. Hence, mothers' appropriate nutritional behaviours during the prenatal and postnatal periods are key to improve child growth. Conversely, maternal undernutrition causes low maternal BMI, which in turn affects the foetus to poor development often associated with small birth size and low birth weight[1,3,21,36]. This finding indicates that mothers of children under 5 should continuously be educated on the best nutritional practices such as exclusive breastfeeding, complementary feeding, and dietary supplementation. These strategies will help ameliorate the risk of acquiring health conditions associated with undernutrition among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no education and primary education compared to those whose mothers had higher education. Mothers who have attained higher education are better informed about improved childcare practices[37], are more empowered to make health decisions[38], practice good personal hygiene[38], are more likely to use the health facility[39], proper feeding practices[36] and childcare in times of illness[36,40]. This finding suggests that mothers with no formal or little education are neglected in nutritional programs that help to eliminate stunting, underweight, and wasting. Hence, they should be given the needed consideration to deal with this persistent health issue.

This study also found that the risk of co-existence of the three dimensions was higher among children whose mothers were not working compared to those whose mothers were working. Women's employment status indicates their ability to afford proper nutritional products and health care services[36,40]. Therefore, if mothers are not employed, the children become highly susceptible or vulnerable because mothers are unlikely to meet their nutritional needs or requirements. Mothers with children under 5 with such disadvantaged backgrounds should be given subsidies on children's nutritional products and perhaps, free access to health care services by governmental and non-governmental organizations. This step will be significant in reducing the risks of the co-existence of stunting, underweight, and wasting among children under 5 years.

The risk of co-existence of the three dimensions was higher among children whose mothers had no antenatal visits during pregnancy compared to those whose mothers had antenatal visits during pregnancy. Specifically, mothers who attend antenatal services are usually educated on the best practices of nutrition and general healthcare, which hitherto would not be known by these mothers[38]. Therefore, mothers who did not have antenatal visits may lack some knowledge about proper nutritional practices, increasing their children's risk of having these undernutrition-related challenges. Regular antenatal visits could reduce children's risk of stunting, being underweight, and wasting, therefore,

mothers should continuously be encouraged to go for antenatal care services in their countries.

Children who were delivered at home compared to children who were delivered at a health facility were found to have a higher risk of co-existence of the three dimensions. Since mothers who deliver at home do not receive any expert nutritional advice from a qualified health practitioner[37], the children of such mothers are at higher risk of having these conditions because of poor and/ or inadequate dietary practices. This finding shows that facility delivery may help reduce the risk of co-existence of stunting, underweight, and wasting among children under 5. Therefore, mothers should regularly be educated on the need to opt for facility delivery because of its positive implications on children's growth.

The risk of co-existence of the three dimensions was higher among children whose mothers were poor and had middle wealth status compared to those whose mothers were rich. Usually, mothers who have an average income may lack the financial capacity to feed themselves and their children properly and adequately[3,17,36], increasing the children's risk of being stunted, underweight or wasted. Likewise, mothers from poor and middle wealth quintiles may not have access to quality nutritional products and health care systems[36,40], making their children more susceptible to having all three nutritional conditions. This finding implies that women from poor economic backgrounds should be assisted with nutritional products and services to facilitate the reduction in the risks of the co-existence of stunting, underweight, and wasting among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no access to media compared to those whose mothers had access to media. Since many people are educated about proper nutritional practices through the mass media[10,11], mothers who have no access to the media may lack certain important nutritional information they need. This information gap could increase children's risk of having all three nutritional conditions through improper dietary practices from their mothers. For instance, mothers' access to appropriate information from the media would help them decide on which proper diets or food commodities are readily available on market for their children. More pragmatic ways of reaching mothers who have no access to media are encouraged. Regular outreach or sensitization programs to target women without access to media for example could help in reducing the risks of the co-existence of stunting, underweight, and wasting among children under 5 years.

Children whose mothers had unimproved toilet facilities were found to have a higher risk of co-existence of the three dimensions of child undernutrition compared to those whose mothers had improved toilet facilities. Insanitary or unhygienic toilet conditions may increase mother-child-environment interactions that may result in increased exposure to childhood diseases and other opportunistic infections (e.g., diarrhoeal episodes, fever) either through consumption of contaminated foods, drinking water or poor environmental sanitation[21]. These conditions have been shown to cause growth retardation in children. Government and non-governmental organizations should support the provision of improved household toilet facilities for poorer communities to help minimize the risks of the co-existence of child undernutrition indicators.

Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having the co-existence of the three dimensions compared to those from Angola. On the other

hand, countries such as Benin, Cameroon, Congo, Gabon, Ghana, Guinea, Kenya, Lesotho, Malawi, Senegal, Zambia, Uganda, Tanzania, Sierra Leone, Zimbabwe, and South Africa had a lower risk among their children having co-existence of the three undernutrition dimensions. The sub-regional and country-specific variations in socio-economic, agro-ecological and geographical characteristics may strongly influence the nutritional status of children because of inadequate food supplies, limited access to arable land for agriculture, unfavourable climatic conditions (e.g., desertification), rapid population growth, and increasing cost of living may determine food access, availability and production in studied countries in SSA[41,42]. Governmental priorities should intensify efforts to minimize the risk of co-existence of stunting, underweight, and wasting among children under age 5 with sound socio-economic and sustainable human capital development.

Conclusions and implications

The study investigated the risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The study found that the prevalence of co-existence of stunting, underweight, and wasting ranged from 0.58 % in the Gambia to 12.14% in Benin. The study also found that the prevalence of co-existence of stunting, underweight, and wasting was high in Western Africa (41.78%) but low in Southern Africa (5.3%). The significant findings show that the disadvantaged have more risks of the co-existence of stunting, underweight, and wasting among under 5 children in selected SSA countries. These findings demonstrate the urgent need for consideration of the co-existence of stunting, wasting and underweight among under-five children in policy design and programming of interventions to eradicate child malnutrition in SSA. In the short-term, national-level policies and interventions needs to be well-tailored considering the compositional characteristics including child's age, sex, birth size; maternal education, working status, place of delivery, antenatal visit; and household's wealth status, access to media and improved toilet facility are required. For instance, such programs could be geared towards improving females' access to education, reducing unemployment, expanding access to the media and using it to promote education on the need for antenatal care. In the long-term, regional policies and coordinated interventions among governments of SSA countries need to be designed to address the disparate prevalence of the co-existence of stunting, wasting and underweight in under-five children across the four geographic regions. The implementation of these at the local-level should consider rural-urban differences in the prevalence of the condition and the risk factors elicited.

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Contributors: IA and BOA developed the study concept. IA performed the data analysis. AS, ED, JBF, JEH, RGA, BA, CA and BOA drafted and revised the manuscript critically for its intellectual content**.** All authors read and approved the final manuscript. AS had the final responsibility to submit the manuscript.

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Ethics Approval and consent to participate

This study used secondary data from the DHS Program. Since we neither interacted directly nor indirectly with the study participants, there was no need for ethical approval. Details on the ethical considerations of the DHS Program could found at https://dhsprogram.com/methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm.

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References

1. Amare ZY, Ahmed ME, Mehari AB. Determinants of nutritional status among children under age 5 in Ethiopia: further analysis of the 2016 Ethiopia demographic and health survey. *Global Health* 2019;15(1):1–11.
2. Anin SK, Saaka M, Fischer F, Kraemer A. Association between Infant and Young Child Feeding (IYCF) Indicators and the Nutritional Status of Children (6–23 Months) in Northern Ghana. Nutrients *2020;* 12, 2565. https://doi.org/10.3390/nu12092565
3. Madiba S, Chelule PK, Mokgatle MM. Attending informal preschools and daycare centers is a risk factor for underweight, stunting and wasting in children under the age of five years in underprivileged communities in South Africa. *International Journal of Environmental Research and Public Health* 2019; 16(14), 2589.
4. Yalew BM, Amsalu F, Bikes D. Prevalence and factors associated with stunting, underweight and wasting: a community based cross sectional study among children age 6-59 months at Lalibela Town, Northern Ethiopia. *J Nutr Disorders Ther* 2014; 4(147), 2161-0509.
5. WHO. Nutrition Landscape Information System (NLIS) Country Profile Indicators: Interpretation Guide; World Health Organization: Geneva, Switzerland, 2010.
6. Akombi BJ, Agho KE, Hall JJ, Wali N, Renzaho A, Merom D. Stunting, wasting and underweight in sub-Saharan Africa: a systematic review. *International Journal of Environmental Research and Public Health* 2017; 14(8), 863.
7. WHO. Global nutrition targets 2025: policy brief series (WHO/NMH/NHD/14.2). Geneva: World Health Organization; 2014. https://apps.who.int/iris/bitstream/handle/10665/149018/WHO_NMH_NHD_14.2_eng.pdf
8. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, Ezzati M, Grantham-McGregor S, Katz J, Martorell R, Uauy R, Maternal and Child Nutrition Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries. *The lancet* 2013; 382(9890), 427-451.

9. World Health Organization. Levels and trends in child malnutrition: key findings of the 2019 edition (No. WHO/NMH/NHD/19.20). World Health Organization. 2019.
10. De Onis M, Onyango A, Borghi E, Siyam A, Blössner M, Lutter C. Worldwide implementation of the WHO child growth standards. *Public Health Nutrition* 2012; 15(9), 1603-1610.
11. De Onis M, Blössner M, Borghi E. Prevalence and trends of stunting among pre-school children, 1990–2020. *Public Health Nutrition* 2012; 15(1), 142-148.
12. World Health Organization. Community-based management of severe acute malnutrition: a joint statement by the World Health Organization, the World Food Programme, the United Nations System Standing Committee on Nutrition and the United Nations Children's Fund. 2007.
13. UNICEF. Levels and trends in child malnutrition, United Nations Children's fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and trends in child malnutrition: key findings of the 2019 edition of the joint child malnutrition estimates. Geneva: World Health Organization; 2019 Licence: CC BY-NC-SA 3.0 IGO; 2019.
14. Central Statistical Agency (CSA)[Ethiopia] and ICF. Ethiopia demographic and health survey, Addis Ababa, Ethiopia and Calverton, Maryland, USA. 2016.
15. Yaya S, Uthman OA, Ekholuenetale M, Bishwajit G, Adjiwanou V. Effects of birth spacing on adverse childhood health outcomes: evidence from 34 countries in sub-Saharan Africa. *J Matern & Neonatal Med* 2020;33(20):3501–8.
16. Armah FA, Ekumah B, Yawson DO, Odoi JO, Afitiri A, Nyieku FE, et al. Predictive Probabilities of Access to Clean Cooking: Evidence from the Demographic and Health Surveys in 31 Countries in Sub-Saharan Africa. 2019;12(3):320–2.
17. Mamabolo RL, Alberts M, Steyn NP, Delemarre-van de Waal HA, Levitt NS. Prevalence and determinants of stunting and overweight in 3-year-old black South African children residing in the Central Region of Limpopo Province, South Africa. *Public Health Nutrition* 2005; 8(5), 501-508.
18. Novignon J, Aboagye E, Agyemang OS, Aryeetey G. Socioeconomic-related inequalities in child malnutrition: evidence from the Ghana multiple indicator cluster survey. *Health Economics Review* 2015; 5(1), 1-11.
19. Khara T, Mwangome M, Ngari M, Dolan C. Children concurrently wasted and stunted: A meta-analysis of prevalence data of children 6–59 months from 84 countries. Maternal & child nutrition. 2018 Apr;14(2):e12516.
20. Boah M, Azupogo F, Amporfro DA, Abada LA. The epidemiology of undernutrition and its determinants in children under five years in Ghana. Plos one. 2019 Jul 31;14(7):e0219665.
21. Khan RE, Raza MA. Determinants of malnutrition in Indian children: new evidence from IDHS through CIAF. Quality & Quantity. 2016 Jan 1;50(1):299-316.
22. Angood C, Khara T, Dolan C, Berkley JA, WaSt Technical Interest Group. Research priorities on the relationship between wasting and stunting. PloS one. 2016 May 9;11(5):e0153221.
23. Corsi DJ, Neuman M, Finlay JE, Subramanian SV. Demographic and health surveys: a profile. *International Journal of Epidemiology* 2012; 41(6), 1602-1613.

24. Aliaga A, Ruilin R. Cluster optimal sample size for demographic and health surveys. In 7th International Conference on Teaching Statistics–ICOTS (Vol. 7, pp. 2-7). 2006.
25. DHS. DHS data source https://dhsprogram.com/data/available-datasets.cfm
26. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, Strobe Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. International journal of surgery. 2014; 12(12), 1495-1499.
27. Collins J, Ward BM, Snow P, Kippen S, Judd F. Compositional, Contextual, and Collective Community Factors in Mental Health and Well-Being in Australian Rural Communities. *Qualitative Health Research* 2017; 27(5), 677–687. https://doi.org/10.1177/1049732315625195
28. Pol LG, Thomas RK. The demography of health and health care. Springer Science & Business Media. 2001.
29. Armah FA, Ekumah B, Yawson DO, Odoi JO, Afitiri AR, Nyieku F.E. Access to improved water and sanitation in sub-Saharan Africa in a quarter century. *Heliyon* 2018; 4(11), e00931. https://doi.org/10.1016/j.heliyon.2018.e00931
30. Ross CE, Mirowsky J. Neighborhood socioeconomic status and health: context or composition? *City & Community* 2008; 7(2), 163–179.
31. Amegah AK, Boachie J, Näyhä S, Jaakkola JJK. Association of biomass fuel use with reduced body weight of adult Ghanaian women. *J Expo Sci Environ Epidemiol* 2019;1.
32. Alemayehu M, Tinsae F, Haileslassie K, Seid O, Gebregziabher G, Yebyo H. Undernutrition status and associated factors in under-5 children, in Tigray, Northern Ethiopia. *Nutrition* 2015; 31(7-8), 964-970.
33. Mya KS, Kyaw AT, Tun T. Feeding practices and nutritional status of children age 6-23 months in Myanmar: A secondary analysis of the 2015-16 Demographic and Health Survey. *PloS one* 2019; 14(1), e0209044.
34. Bork KA, Diallo A. Boys are more stunted than girls from early infancy to 3 years of age in rural Senegal. *The Journal of Nutrition* 2017; 147(5), 940-947.
35. Tumilowicz A, Habicht JP, Pelto G, Pelletier DL. Gender perceptions predict sex differences in growth patterns of indigenous Guatemalan infants and young children. *The American Journal of Clinical Nutrition* 2015; 102(5), 1249-1258.
36. Mukabutera A, Thomson DR, Hedt-Gauthier BL, Basinga P, Nyirazinyoye L, Murray M. Risk factors associated with underweight status in children under five: an analysis of the 2010 Rwanda Demographic Health Survey (RDHS). *BMC Nutrition* 2016; 2(1), 1-12.
37. Oyekale AS. Factors explaining acute malnutrition among under-five children in Sub-Sahara Africa (SSA). *Life Sci J* 2012; 9, 2101-7.
38. Keats A. Women's schooling, fertility, and child health outcomes: Evidence from Uganda's free primary education program. *Journal of Development Economics* 2018; 135, 142-159.
39. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Poor nutrition status and associated feeding practices among HIV-positive children in a food secure region in Tanzania: a call for tailored nutrition training. *PloS one* 2014; 9(5), e98308.
40. Iannotti LL, Dulience SJL, Green J, Joseph S, François J, Antenor ML, ... Nickerson NM. Linear growth increased in young children in an urban slum of Haiti: a

randomized controlled trial of a lipid-based nutrient supplement. *The American Journal of Clinical Nutrition* 2014; 99(1), 198-208.

41. Lopriore C, Muehlhoff E. Food security and nutrition trends in West Africa—Challenges and the way forward. In Proceedings of the 2nd International Workshop on Food-based Approaches for a Healthy Nutrition, Ouagadougou, Burkina. 2003; 23–28.
42. Salami A, Kamara AB, Brixiova Z. Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities; African Development Bank: Tunis, Tunisia, 2010.

Figures

Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

Tables

Table 1: Distribution of the relevant variables and characteristics of under-five children in SSA

Variable	%	Variable	%
Age of child		Urbanicity	
0	30.87	Urban	33.21
1	28.42	Rural	66.79
2	20.22	Place of delivery	
3	12.40	Home	31.33
4	8.09	Health facility	67.51
Sex of child		Other	1.16
Male	50.47	Wealth status	
Female	49.53	Poor	42.41
Birth order		Middle	20.28
1	19.52	Rich	37.31
2 to 4	48.09	Age of household head	
5 and above	32.39	Young-adults	43.08
Perceived size at birth		Middle-aged adults	43.76
Large	33.71	Old-aged adults	13.16
Average	49.74	Sex of household head	
Small	16.54	Male	79.77
Mother's characteristics		Female	20.23
Maternal age		Access to electricity	
15-19	7.13	No	69.20
20-49	92.87	Yes	30.80
Educational attainment			
No education	41.82	Type of toilet facility	
Primary	31.26	Improved	42.47
Secondary	23.82	Unimproved	57.53
Higher	3.10	Source of drinking water	
Working status		Improved	65.63
No	35.49	Unimproved	34.37
Yes	64.51	Type of cooking fuel	
Antenatal visits during pregnancy		Clean	89.76
No	10.76	Unclean	10.24
Yes	89.24	Geographic region	
Postnatal check within 2 months		Western	41.78
No	58.49	Eastern	32.84
Yes	41.51	Central	20.08
Access to media (tv/radio/newspaper)		South Africa	5.30
Yes	35.33		
No	64.67		(N=127,487)

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604 Table 2: Prevalence and association of the co-existence of stunting, underweight and wasting with independent variables

Variable	Co-existed Weighted % (95% CI)	Variable	Co-existed Weighted % (95% CI)	Variable	Co-existed Weighted % (95% CI)
Age of child (p<0.001)		**Place of delivery (p<0.001)**		**Country (p<0.001)**	
<1	1.75 (1.6-1.9)	Home	4.36 (4.2-4.6)	Angola	2.46 (2.1-2.8)
1	4.44 (4.2-4.7	Health facility	1.96 (1.9-2.1)	Benin	2.04 (1.8-2.2)
2	3.01 (2.8-3.2)	Other	2.45 (1.7-3.3)	Burkina Faso	5.31 (4.9-5.8)
3	1.62 (1.4-1.8)	**Wealth status (p<0.001)**		Burundi	3.76 (3.2-4.4)
4	1.33 (1.1-1.6)	Poor	3.46 (3.3-3.6)	Cameroon	1.27 (0.9-1.7)
Sex of child (p<0.001)		Middle	2.74 (2.5-2.9)	Chad	5.86 (5.2-6.5)
Male	3.43 (3.3-3.6)	Rich	1.86 (1.7-2.0)	Comoros	1.98 (1.3-2.9)
Female	1.99 (1.9-2.1)	**Age of household head (p = 0.2760**		Congo	0.98 (0.7-1.5)
Birth order (p<0.001)		Young-adults	2.65 (2.5-2.8)	Cote d'Ivoire	2.28 (1.7-3.0)
1	2.25 (2.1-2.4)	Middle-aged adults	2.76 (2.6-2.9)	DR Congo	2.66 (2.2-3.2)
2 to 4	2.56 (2.4-2.7)	Old-aged adults	2.8 (2.6-3.1)	Ethiopia	3.64 (3.2-4.1)
5 and above	3.23 (3.1-3.4)	**Sex of household head (p<0.001)**		Gabon	0.63 (0.3-1.0)
Perceived size at birth (p<0.001)		Male	2.82 (2.7-2.9)	The Gambia	3.61 (2.4-5.2)
Large	1.78 (1.7-1.9)	Female	2.33 (2.1-2.5)	Ghana	1.37 (0.9-2.0)
Average	2.6 (2.5-2.7)	**Access to electricity (p<0.001)**		Guinea	2.26 (1.7-2.9)
Small	4.98 (4.7-5.3)	No	3.21 (3.1-3.3)	Kenya	0.94 (0.7-1.2)

Maternal age (P = 0.080)		Yes	1.61 (1.5-1.7)	Lesotho	0.86 (0.7-1.0)
		Access to media			
15-19	2.78 (2.5-3.1)	**(tv/radio/newspaper) (p<0.001)**		Liberia	2.37 (1.7-3.1)
20-49	2.71 (2.6-2.8)	Yes	2.14 (2.0-2.2)	Malawi	1.03 (0.7-1.4)
Educational attainment					
(p<0.001)		No	3.78 (3.6-4.0)	Mali	3.62 (2.5-4.1)
No education	4.19 (4.0-4.4)	**Type of toilet facility (p<0.001)**		Namibia	1.99 (1.2-3.1)
Primary	2.09 (2.0-2.2)	Improved	1.76 (1.6-1.9)	Nigeria	4.1 (3.7-4.6)
Secondary	1.22 (1.1-1.3)	Unimproved	3.43 (3.3-3.6)	Rwanda	6.17 (5.5-6.9)
		Source of drinking water			
Higher	0.66 (0.4-1.0)	**(p<0.001)**		Senegal	2.43 (1.8-3.2)
				Sierra	
Working status (p<0.001)		Improved	2.54 (2.4-2.6)	Leone	1.94 (1.4-2.5)
				South	
No	3.13 (3.0-3.3)	Unimproved	3.06 (2.9-3.2)	Africa	0.18 (0.02-0.8)
Yes	2.48 (2.4-2.6)	**Type of cooking fuel (p<0.001)**		Tanzania	1.86 (2.1-3.5)
Antenatal visits during					
pregnancy (p<0.001)		Clean	0.98 (0.8.2-1.2)	Togo	2.72 (2.1-3.4)
No	5.41 (5.0-5.8)	Unclean	2.92 (2.8-3.0)	Uganda	1.2 (0.8-1.7)
Yes	2.39 (2.3-2.5)	**Urbanicity (p<0.001)**		Zambia	1.22 (1.0-1.5)
Postnatal check within 2					
months (p<0.001)		Urban	1.73 (1.6-1.9)	Zimbabwe	0.78 (0.5-1.1)
No	2.93 (2.8-3.1)	Rural	3.21 (3.1-3.3)	**Geographic region (p<0.0010**	
Yes	2.42 (2.3-2.6)			Western	3.11 (3.0-2.3)
				Eastern	2.43 (2.3-2.6)
				Central	2.87 (2.7-3.1)
				South	
				Africa	0.88 (0.66-1.1)

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607 **Table 3: Multinomial regression showing risk factors of co-existence of stunting, underweight, and wasting**

Variable	Base outcome (Ref: Normal)					
	Single and two dimensions			Co-existence of three-dimensions		
	RRR	95% CI		RRR	95% CI	
Age of child (Ref:0)						
1	2.008***	1.93	2.089	3.714***	3.319	4.156
2	2.624***	2.514	2.739	2.827***	2.48	3.222
3	2.122***	2.018	2.231	1.464***	1.227	1.748
4	1.504***	1.417	1.597	1.051	0.84	1.315
Sex of child (Ref: Male)						
Female	0.752***	0.731	0.775	0.468***	0.429	0.51
Birth order (Ref: 1)						
2	0.938**	0.896	0.981	1.002	0.875	1.146
5 and above	0.969	0.92	1.021	0.995	0.858	1.155
Perceived size at birth (Ref: Large)						
Average	1.32***	1.276	1.365	1.756***	1.574	1.958
Small	1.931***	1.846	2.02	3.818***	3.383	4.308
Maternal age (Ref: 15-19)						
20-49	0.834***	0.78	0.891	0.881	0.735	1.056
Educational attainment (Ref: Higher)						
No education	2.624***	2.305	2.987	3.291***	1.961	5.522
Primary	2.189***	1.927	2.487	2.381***	1.417	4.001
Secondary	1.751***	1.545	1.985	1.617	0.971	2.691
Working status (Ref: Yes)						
No	1.018	0.984	1.053	1.195***	1.086	1.314
Antenatal visits during pregnancy (Ref: Yes)						<0.001
No	1.139***	1.079	1.201	1.364***	1.208	1.541
Postnatal check within 2 months (Ref: Yes)						
No	0.98	0.946	1.015	0.977	0.879	1.086
Place of delivery (Ref: Health facility)						

Home	1.183***	1.137	1.23	1.372***	1.232	1.529
Other	1.046	0.912	1.201	1.047	0.71	1.543
Wealth status (Ref: Rich)						
Poor	1.297***	1.235	1.361	1.408***	1.235	1.605
Middle	1.195***	1.138	1.254	1.214**	1.054	1.397
Age of household head (Ref: Young-adult)						
Middle-aged adults	0.954**	0.921	0.987	1.01	0.913	1.118
Old-aged adults	0.974	0.93	1.021	1.065	0.936	1.213
Sex of household head (Ref: Male)						
Female	0.977	0.94	1.015	1.035	0.925	1.159
Access to media (tv/radio/newspaper) (Ref: Yes)						
No	1.079***	1.042	1.117	1.255***	1.144	1.377
Access to electricity (Ref: Yes)						
No	1.136***	1.083	1.191	1.062	0.922	1.225
Type of toilet facility (Ref: Improved)						
Unimproved	1.027	0.991	1.065	1.158**	1.032	1.3
Source of drinking water (Ref: Improved)						
Unimproved	0.959**	0.928	0.99	0.968	0.885	1.058
Type of cooking fuel (Ref: Clean)						
Unclean	1.177***	1.089	1.271	1.316	0.97	1.787
Urbanicity (Ref: Urban)						
Rural	1.05**	1.006	1.095	0.943	0.832	1.069

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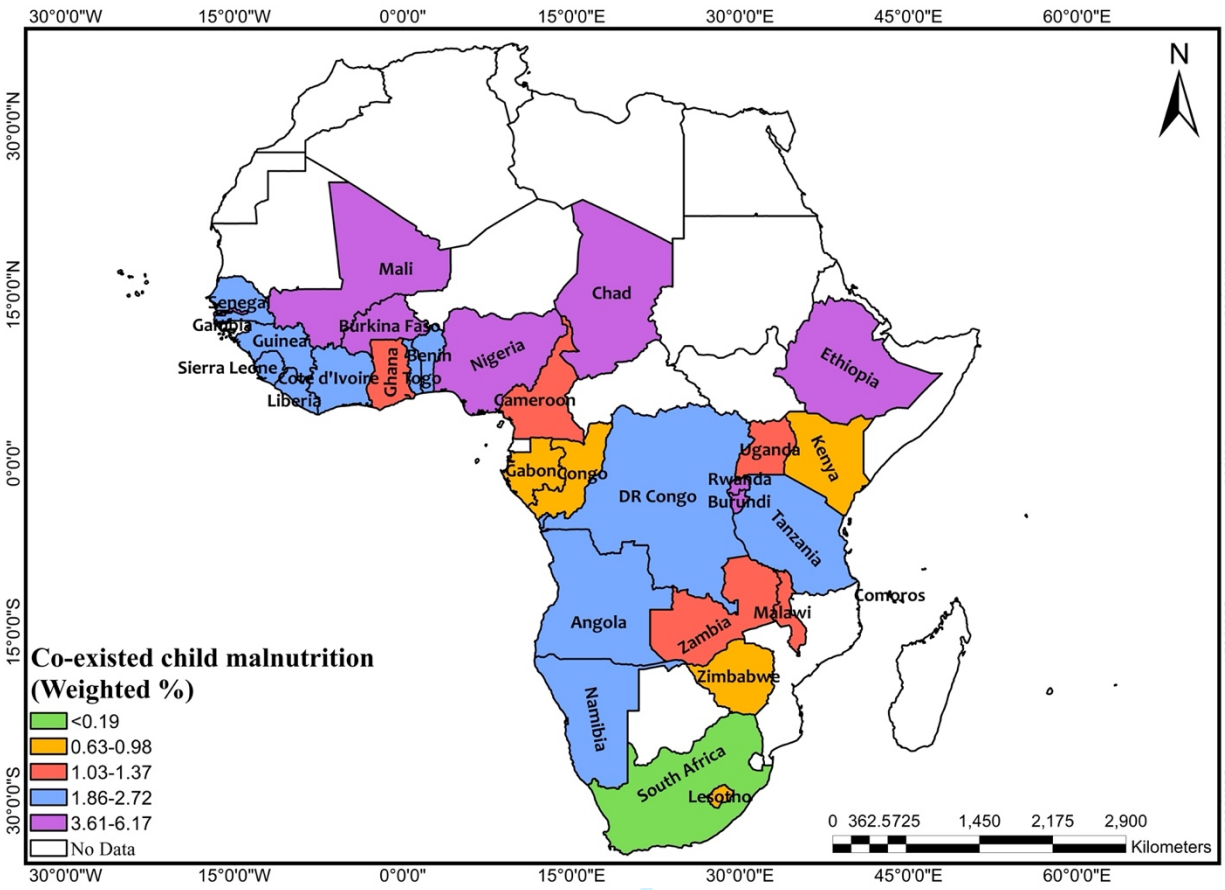

Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

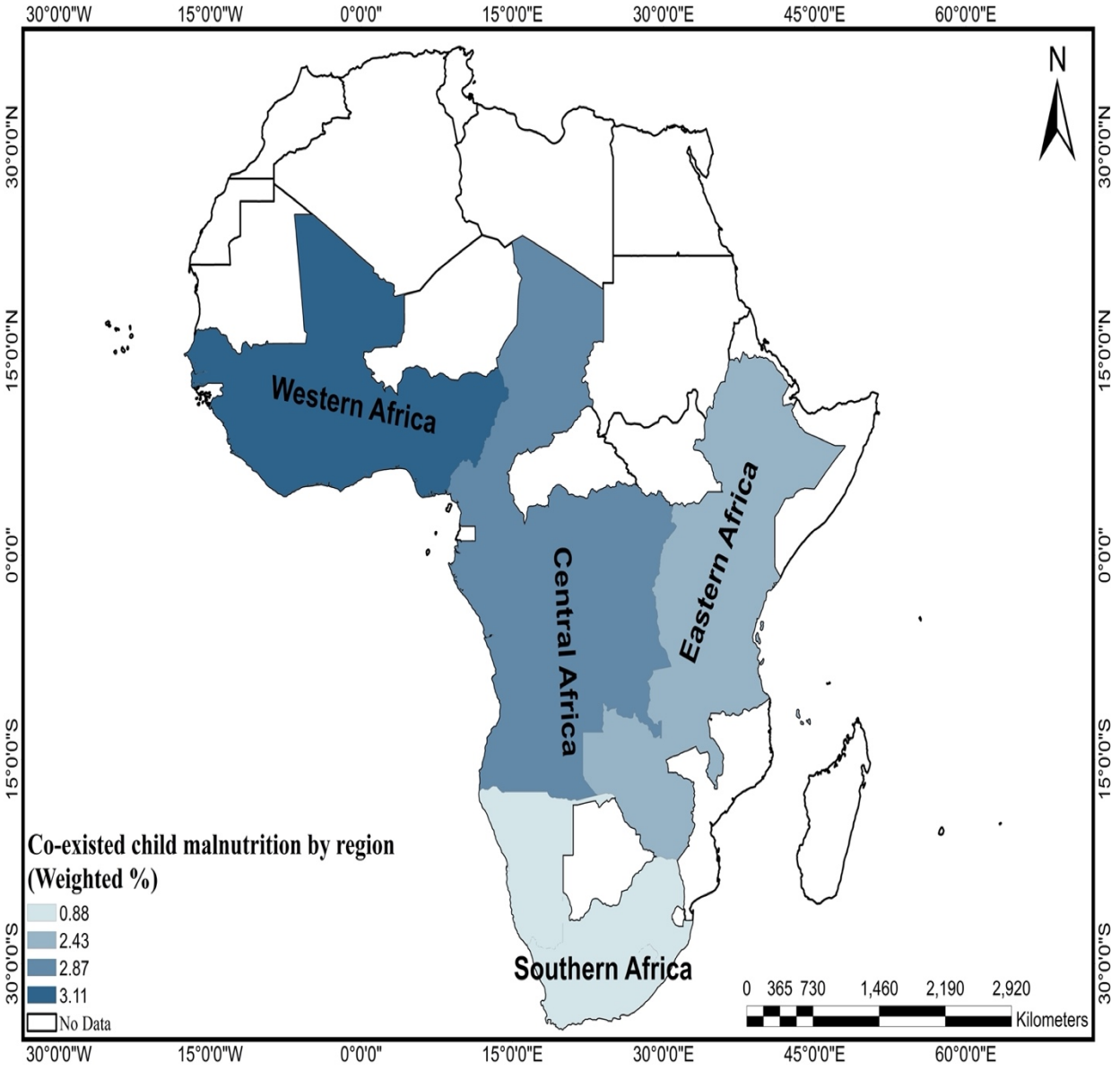

Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

Supplementary Tables

Appendix 1: Distribution of sample by country

Country	Survey year	n	%
Angola	2015-16	7,318	5.74
Benin	2017-18	15,473	12.14
Burkina Faso	2010	8,908	6.99
Burundi	2016-17	4,172	3.27
Cameroon	2018	2,911	2.28
Chad	2014-2015	5,999	4.71
Comoros	2012	1,320	1.03
Congo	2013	2,609	2.05
Cote d'Ivoire	2011-12	2,174	1.71
Congo DR	2013-14	4,806	3.77
Ethiopia	2016	6,573	5.16
Gabon	2012	1,960	1.54
Gambia	2013	743	0.58
Ghana	2014	1,896	1.49
Guinea	2018	2,237	1.75
Kenya	2014	6,066	4.76
Lesotho	2014	1,012	0.79
Liberia	2013	1,946	1.53
Malawi	2015-16	4,027	3.16
Mali	2018	5,653	4.43
Namibia	2013	905	0.71
Nigeria	2018	7,379	5.79
Rwanda	2014-15	4,408	3.46
Senegal	2010-11	1,944	1.52
Sierra Leone	2019	2,689	2.11
South Africa	2016	855	0.67
Tanzania	2015-16	6,061	4.75
Togo	2013-14	2,220	1.74
Uganda	2016	2,891	2.27
Zambia	2018	6,347	4.98
Zimbabwe	2015	3,987	3.13

Appendix 2: Multicollinearity diagnosis				
Variable	VIF	SQRT VIF	Tolerance	R-Squared
Age of child	1.05	1.02	0.9547	0.0453
Sex of child	1.01	1	0.9948	0.0052
Birth order	1.36	1.17	0.7366	0.2634
Perceived size at birth	1.02	1.01	0.9798	0.0202
Age at child birth	1.22	1.1	0.8224	0.1776
Educational attainment	1.51	1.23	0.664	0.336
Working status	1.07	1.03	0.9357	0.0643
Antenatal visits during pregnancy	1.25	1.12	0.7976	0.2024
Postnatal check within 2 months	1.1	1.05	0.9098	0.0902
Place of delivery	1.31	1.15	0.7617	0.2383
Wealth status	1.8	1.34	0.5554	0.4446
Age of household head	1.05	1.02	0.9546	0.0454
Sex of household head	1.03	1.02	0.9702	0.0298
Access to media (tv/radio/newspaper)	1.26	1.12	0.7913	0.2087
Access to electricity	1.71	1.31	0.5837	0.4163
Type of toilet facility	1.35	1.16	0.7404	0.2596
Source of drinking water	1.09	1.04	0.9191	0.0809
Type of cooking fuel	1.31	1.14	0.7653	0.2347
Urbanicity	1.58	1.26	0.6319	0.3681
Country	1.17	1.08	0.8579	0.1421
Mean VIF	1.26			

Appendix 3: **Country-level risk of co-existence of stunting, wasting, and underweight**

	Base outcome (Ref: Normal)					
	Single and two dimensions			Co-existence of three-dimensions		
	RRR	95% CI		RRR	95% CI	
Country (Ref: Angola)						
Benin	0.651***	0.598	0.708	0.625***	0.489	0.798
Burkina Faso	0.952	0.866	1.046	1.946***	1.526	2.481
Burundi	1.580***	1.424	1.753	2.049***	1.545	2.718
Cameroon	0.669***	0.593	0.756	0.398***	0.261	0.609
Chad	0.910	0.823	1.007	1.505**	1.184	1.913
Comoros	0.883	0.745	1.046	0.656	0.378	1.138
Congo	0.674***	0.580	0.783	0.472**	0.279	0.800
Cote d'Ivoire	0.734***	0.638	0.844	0.739	0.492	1.109
DR Congo	1.229***	1.100	1.373	1.351	0.988	1.847
Ethiopia	0.810***	0.726	0.904	0.813	0.604	1.095
Gabon	0.495***	0.415	0.59	0.319**	0.128	0.796
Gambia	0.732**	0.603	0.889	1.001	0.618	1.620
Ghana	0.453***	0.386	0.531	0.545**	0.346	0.857
Guinea	0.798***	0.705	0.904	0.726	0.509	1.036
Kenya	0.553***	0.498	0.615	0.321***	0.230	0.449
Lesotho	0.777**	0.654	0.924	0.369***	0.177	0.772
Liberia	0.658***	0.565	0.768	0.776	0.484	1.243
Malawi	0.794***	0.708	0.889	0.447***	0.291	0.687
Mali	0.600***	0.541	0.664	1.006	0.769	1.316
Namibia	0.680***	0.568	0.815	0.849	0.505	1.426
Nigeria	0.953	0.868	1.046	1.527**	1.183	1.972
Rwanda	1.059	0.954	1.176	1.991***	1.541	2.571
Senegal	0.660***	0.572	0.761	0.643*	0.434	0.952
Sierra Leone	0.641***	0.567	0.725	0.656*	0.447	0.963
South Africa	0.788*	0.634	0.979	0.108***	0.033	0.352
Tanzania	0.772***	0.699	0.851	0.699**	0.512	0.954
Togo	0.557***	0.490	0.633	0.838	0.590	1.190
Uganda	0.627***	0.556	0.708	0.421***	0.278	0.637
Zambia	0.904*	0.818	0.998	0.519***	0.366	0.736
Zimbabwe	0.693***	0.620	0.775	0.344***	0.214	0.554

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Risk factors associated with the co-existence of stunting, underweight, and wasting in children under five: Analysis of cross-sectional surveys from 31 sub-Saharan African countries

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ABSTRACT

Objective: This study investigated the risk factors associated with the co-existence of stunting, underweight, and wasting among children under age five in sub-Saharan Africa(SSA).

Methods: Data from 31 sub-Saharan African countries were pooled from the Demographic and Health Surveys collected between 2010 and 2019. We examined the risk of co-existence of undernutrition using multinomial logistic regression models, with results presented as relative risk ratios with their respective confidence intervals.

Outcome measures: The outcome variables were three child anthropometrics: stunting (height-for-age z-scores); underweight (weight-for-age z-scores); and wasting (weight-for-height z-scores).

Results: The prevalence of co-existence of stunting, underweight, and wasting varied across countries and sub-regions, with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting as Benin (12.14%) and Gambia (0.58%) respectively. The risk of co-existence of the three undernutrition dimensions was higher among children age 1 year compared to those aged 0. The risk of co-existence of the three dimensions was higher among female children, those with small size at birth, those whose mothers had no education, not working, had no antenatal visits during pregnancy, children delivered at home, those whose mothers were poor, had no access to media and children whose mothers had unimproved toilet facility.

Conclusion: Findings suggest the urgent need for consideration of the co-existence of stunting, wasting and underweight among under-five children in policy design and programming of interventions to eradicate child malnutrition in SSA. In the short-term, national-level policies and interventions need to be well-tailored considering the compositional characteristics. In the long-term, regional policies and coordinated interventions among governments of SSA countries need to be designed to address the disparate prevalence of the co-existence of stunting, wasting and underweight in under-five children across the four geographic regions.

Keywords: co-existence; stunting; underweight; wasting; children under five; sub-Saharan Africa

Strength and Limitations

- The use of nationally representative data ensures that our findings are generalizable and replicable in the 31 SSA countries included in this study.
- Findings contribute to bridging the gaps identified in the current research on CNS by including multiple indicators (stunting, underweight, and wasting) in the concurrent measurement of our outcome variable, compared to the unitary assessment on undernutrition that currently dominates literature.
- The study relied on secondary data, the analysis was limited to only variables that were in the dataset. Hence, interpretations and inferences made from current findings must be limited to only these observed variables.
- Also, the DHS employs cross-sectional designs which restrict causality on the noted outcomes.
- The key variables were self-reported by the mothers, and therefore, there is the likelihood of recall bias and other social desirability concerns in the present study.

BACKGROUND

Undernutrition among children under 5 years remains a major public health problem across many low-and middle-income countries[1-3]. Factors such as insufficient food intake, diarrhoea, recurring infections, poor sanitation practices, and low parental education have been identified as significant contributors to the high prevalence of undernutrition during childhood[1,4,5]. Despite the numerous interventions rolled out to address childhood undernutrition especially in sub-Saharan Africa where the phenomenon is quite pervasive, the progress seems to be insignificant[6,7]. For example, a study reported that child undernutrition accounted for nearly half (45%) of the child mortality rate in low-and middle-income countries[8]. Aside from that, it was reported in 2018 that about 149 million and 49 million children under age 5 were stunted and wasted respectively[9].

Three main indicators that are often used to represent undernutrition are underweight or low weight for age, stunting or low height for age, and wasting or low weight for height[2,10-12]. Among the three indicators of undernutrition, stunting has been identified as the problem with the greatest magnitude among under 5 children in developing countries[2,3]. Even though the prevalence of stunting in sub-Saharan Africa is declining, it is worth noting that it is still above 30%[13] which is undeniably high. Research also indicates that the country-specific prevalence of stunting, underweight and wasting is still high[2,3]. For instance, in Ethiopia, the prevalence of wasting and stunting were 10% and 38% respectively[14]. Additionally, the prevalence of stunting, underweight and wasting among children in South Africa were 35.8%, 20.5%, and 17.2%[3]. Likewise, Anin et al.[2] reported 33.2%, 14.1%, 27% and 2.6% of prevalence in stunting, wasting, underweight and overweight among infants (6-23 months) across Northern Ghana.

Previous studies have investigated the compositional and contextual risk factors associated with either stunting, underweight or wasting among children under 5 years and found the age of a child, sex of the child, child's size at birth, mother's age during childbirth, mother's educational level, birth order, place of residence and mother's body mass index (BMI) as associated factors[1-3,15,16]. Other studies also found a significant linkage between household wealth quintile and maternal short stature, and nutritional status of children under 5[17,18]. Regarding the sex of a child, for example, female children were found to be less likely to suffer from stunting compared to males[1,3].

Apart from studies that have examined the factors associated with either stunting, underweight, and wasting, some scholars have begun looking at predictors of the co-existence of any two or three of the indicators of malnutrition. A study in 84 countries that examined the prevalence and predictors of co-existence of stunting and wasting found sex and age of children as significant predictors[19]. Other studies in Ghana[20] and India[21] also examined the co-existence of stunting, underweight, and wasting and found birth interval, birth weight, dietary diversity, place of delivery, wealth index, mother's BMI, mother's educational level, and partners' educational level as associated factors. The need to examine the co-existence of stunting, underweight and wasting is important because not much work has been done on that subject and hence children who concurrently suffer from stunting, underweight, and wasting are less likely to be reached in malnutrition prevention programmes, especially in SSA. For instance, some scholars have indicated that despite evidence that wasting and stunting are global public health problems that frequently co-exist, they are usually separated in terms of policy, guidance, programming

and financing[22]. This creates a gap in the literature that needs to be filled. Despite the detrimental consequences of undernutrition on the health and wellbeing of children under 5 in SSA, studies utilizing current, and nationally representative data to investigate the risk factors associated with the co-existence of stunting, underweight, and wasting among this age group are absent in the literature. Studies presenting empirical analyses of the co-existence of these three indicators of child undernutritionin SSA are absent in extant literature making it difficult for policymakers and nutritional experts to provide up-to-date trends with appropriate strategies to curb the situation in the sub-region. This research lag presents a void in extant literature which this study seeks to bridge. Therefore, the study investigated the risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from the Demographic Health Survey (DHS) conducted in 31 countries between 2010 and 2019. The findings of the study could contribute to the formulation of policies and interventions to respond to the nutritional needs of children under 5 years and also suggest pragmatic ways of reducing undernutrition among children in the sub-region.

METHODS

Data Source

The dataset included 127,487 children under the age of 5 years from 31 sub-Saharan African countries (Figure 1) were pooled from the most current Demographic and Health Surveys (DHS) conducted between 2010 and 2019 (Appendix 1). Specifically, the data were pooled from the children's files in each of the countries. The DHS Program has conducted over 400 surveys in over 90 developing countries around the world since 1984 every five years[23]. The program implements cross-sectional surveys to gather nationally-representative data, analyze and disseminate accurate information on important demographic and health indicators spanning population, nutrition, and diseases. For all surveys, standardized protocols designed for each target group including children, women, and men at the household level are employed to allow for cross-national comparisons. Stratified two-stage sampling involving first, the listing of enumeration areas and selection of clusters, and then a random selection of households in each cluster. The detailed sampling method can be found in a previous study[24]. The dataset is freely available for download at: https://dhsprogram.com/data/available-datasets.cfm[25]. The Strengthening Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed in writing the manuscript[26].

Study Variables

Outcome Variable

The outcome variable considered in this study is derived from three child anthropometric variables including stunting (height-for-age z-scores); underweight (weight-for-age z-scores) and wasting (weight-for-height z-scores). The DHS (2021) specifies categorization for each of these variables following the WHO child growth standard. Each of the three variables we coded into "0" for "Normal" and "1" for "Stunting", "underweight" and "Wasting" respectively.

These three variables were then added to generate the outcome variable "Co-existed undernutrition" with scores (discrete) ranging from 0 to 3 where 0 implies "Normal", that is, children with none of the three conditions; 1 implies "Single burden", that is, the child suffers from one of the three conditions; 2 indicates that child suffers from "Two burdens" out of the three; and 3 shows "Co-existed", that is, the child suffers from all three conditions of undernutrition. For parsimony, children who suffered from "Single burden" and those who suffered from "Two burdens" were added resulting in the variable "Co-existed undernutrition" with three response categories: 0=Normal; 1=One or two burdens; and 3=co-existed.

Independent Variables

Several risk factors spanning compositional to contextual factors have been associated with child undernutrition. The relevant biosocial characteristics and sociocultural factors related to the child, mother, household head and the household together form compositional factors[27,28]. Factors that describe location or "place-based" variables are contextual factors[20,27,29,30]. The relevant compositional factors considered include the age of the child; sex of the child; birth order of child; perceived size at birth; mother's age; educational attainment; working status; antenatal visits during pregnancy; postnatal check within 2 months; and place of delivery. At the household level, relevant variables included are the wealth status; the age of household head; sex of household head (male and female); access to electricity; and access to media which was derived from the three variables "access to television", "radio" and "newspaper". Household basic needs including the type of toilet facility (re-coded into "improved" and unimproved"[29]; source of drinking water (re-coded as "improved" and "unimproved"[29], and type of household cooking fuel (re-coded into "clean" and "unclean" [29,31] are also considered. The contextual factors considered are urbanicity and the country of origin of the participant.

Data Analyses

The statistical analysis of the data was performed using the Stata SE software version 14.2. The "svyset" command was first used to declare the data as survey data to prevent the potential effects of the complex sampling techniques on the analyses. The sample weight variable in the DHS was used to provide weighted samples in the analyses. To understand the distributions of the variables, the data were summarized and presented in tables using descriptive statistics (frequencies, weighted percentages, and 95% confidence intervals (CIs) of percentages). We further integrated the data into a GIS environment and presented the distribution of key variables across the study countries and geographic regions in map images (Figure 1 and Figure 2). This approach enhances the visualization of the data and understanding of the context of the study. The associations between the co-existence of undernutrition and each of the risk factors considered were assessed using the chi-square test of independence, with results presented in a contingency table. The risk factors as independent variables were then subjected to collinearity diagnosis tests, including Variance Inflation Factors (VIF), Square VIF, Tolerance, and R-squared. This was done to ascertain whether the independent variables were actually "independent", that is, are not correlated with one another and will not share variance in the outcome variable. Results from the multicollinearity diagnoses test (See Appendix 2) show that the variables were not correlated (Mean VIF=1.26; Maximum VIF=1.71; Minimum VIF=1.02). To determine

the risk factors associated with the co-existence of undernutrition, a multinomial regression model was implemented. All statistical tests were conducted at $p<0.05$.

Ethical Approval

This study used secondary data from the DHS Program. Since we neither interacted directly nor indirectly with the study participants, there was no need for ethical approval. Details on the ethical considerations of the DHS Program could be found at https://dhsprogram.com/methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm.

Patient and public involvement

Patients and the public were not involved in the design and conduct of this research

Results

Distribution of sample characteristics

The study included a total of 127,487 under-five children. It is found that most (30.87%) of the children were less than a year (Table 1). With regards to sex, both males and females constituted approximately half of the sample. A majority of the children (92.87%) were born to mothers aged between 20 to 49years while only 7.13% were born to mothers aged 15 to 19years. In terms of education, most (41.82%) of the children were born to mothers with no formal education. Only 3.10% of the children were born to a mother with a higher level of educational attainment. Further, 42.1% of the children were born in poor households while 37.21% were born in rich households. More than half (57.53%) of the children lived in a household with unimproved toilet facilities. However, most (65.63%) of the children lived in households with access to improved drinking water sources. Similarly, a majority (89.76%) of the children lived in households using clean cooking fuel (Table 1).

As shown in Appendix 2, the prevalence of co-existence of stunting, underweight, and underweight varied across countries and sub-regions, with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting as Rwanda (6.17%) and South Africa (0.18%) respectively (Figure 1). In terms of sub-region, the highest prevalence of co-existence of stunting, underweight, and wasting was observed in Western Africa (3.11%) and the lowest prevalence in Southern Africa (0.88%) (Figure 2).

Significant associations between all the independent variables and co-existence of stunting, wasting, and underweight, except maternal age and age of household head, were identified (Table 2).

Table 1

Figure 1

Figure 2

Table 2

Risk factors of the co-existence of stunting, wasting and underweight

Table 3 shows the results of the multinomial regression analysis of the risk factors of co-existence of dimensions of undernutrition (stunting, underweight, and wasting) among

children under five years in the SSA. Age of child, size of the child at birth, sex of the child, birth order, educational level, maternal age, ANC attendance, place of delivery, source of drinking water, sex of household head, wealth index, access to electricity and place of residence were associated with one or two dimensions of undernutrition. See Appendix 3 for country-level risk of co-existence of stunting, wasting, and underweight.

Regarding the co-existence of the three dimensions of undernutrition (stunting, underweight, and wasting), age of the child, sex of the child, perceived birth size, maternal educational attainment, working status, antenatal visits during pregnancy, place of delivery, wealth status, access to media, and type of toilet facility were found to be significant risk factors (Table 3).

Table 3

DISCUSSION

The study investigated the risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The study found that the countries with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting were Benin and Gambia respectively. In terms of geographic region, the highest prevalence of co-existence of stunting, underweight, and wasting was observed in Western Africa and the lowest prevalence in Southern Africa. The disparities in the prevalence among the countries and geographical regions could be attributed to the nutritional practices and beliefs practised in the countries and geographical regions. Differences in the health policies provided by governments in the various countries could also account for the disparities noted. This finding implies that countries that have high prevalence should take critical lessons from the countries that are doing well regarding the implementation of nutritional policies and interventions (e.g., increasing dietary supplementation, increasing dietary diversity) that target the reduction of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa[2].

Similar to previous studies[1,3], this study found that children aged 1 year, 2 years, and 3 years were at greater risk of having co-existence of all the three forms of undernutrition compared to those aged 0. A plausible reason for this finding could be that as children grow their energy needs also increase[1], increasing their risk of having all three nutritional conditions. Alternatively, since these nutritional conditions may manifest after long durations of improper nutritional practices or undernutrition[1,3], older children may be at higher risk of having all three nutritional conditions. The finding suggests that complementary foods given to children as they grow are inadequate. To reduce the risk of co-existence of stunting, underweight, and wasting among under 5 children, the health sectors in the various countries should invest heavily in providing adequate complementary feeding to this category of children.

Corroborating the findings of other studies[1,3,32,33], this study also found that children who were females were less likely to have a co-existence of the three dimensions of undernutrition compared to their male counterparts. An acceptable explanation for this finding could be the biological variations in morbidity between males and females at that young age[3]. It is also possible that since male children have higher birth weight compared to females, they require more energy[1,34], which increases the risk of males having all three

nutritional conditions. Moreover, male children are perceived to be hungrier than females, therefore breastfeeding alone could be insufficient or inadequate[3,35], increasing their susceptibility to having the three nutritional conditions. The finding suggests that male children should be given critical attention in the development and implementation of nutritional programs (e.g., dietary supplementation) to mitigate the co-existence of stunting, underweight, and wasting among these male children under 5 years.

The study found that the risk of co-existence of the three dimensions of undernutrition was higher among children with the average size at birth and small size at birth compared to children with large size at birth. It has been proven that undernutrition in children is partly influenced by maternal nutrition practices. Hence, mothers' appropriate nutritional behaviours during the prenatal and postnatal periods are key to improve child growth. Conversely, maternal undernutrition causes low maternal BMI, which in turn affects the foetus to poor development often associated with small birth size and low birth weight[1,3,21,36]. This finding indicates that mothers of children under 5 should continuously be educated on the best nutritional practices such as exclusive breastfeeding, complementary feeding, and dietary supplementation. These strategies will help ameliorate the risk of acquiring health conditions associated with undernutrition among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no education and primary education compared to those whose mothers had higher education. Mothers who have attained higher education are better informed about improved childcare practices[37], are more empowered to make health decisions[38], practice good personal hygiene[38], are more likely to use the health facility[39], proper feeding practices[36] and childcare in times of illness[36,40]. This finding suggests that mothers with no formal or little education are neglected in nutritional programs that help to eliminate stunting, underweight, and wasting. Hence, they should be given the needed consideration to deal with this persistent health issue.

This study also found that the risk of co-existence of the three dimensions was higher among children whose mothers were not working compared to those whose mothers were working. Women's employment status indicates their ability to afford proper nutritional products and health care services[36,40]. Therefore, if mothers are not employed, the children become highly susceptible or vulnerable because mothers are unlikely to meet their nutritional needs or requirements. Mothers with children under 5 with such disadvantaged backgrounds should be given subsidies on children's nutritional products and perhaps, free access to health care services by governmental and non-governmental organizations. This step will be significant in reducing the risks of the co-existence of stunting, underweight, and wasting among children under 5 years.

The risk of co-existence of the three dimensions was higher among children whose mothers had no antenatal visits during pregnancy compared to those whose mothers had antenatal visits during pregnancy. Specifically, mothers who attend antenatal services are usually educated on the best practices of nutrition and general healthcare, which hitherto would not be known by these mothers[38]. Therefore, mothers who did not have antenatal visits may lack some knowledge about proper nutritional practices, increasing their children's risk of having these undernutrition-related challenges. Regular antenatal visits could reduce children's risk of stunting, being underweight, and wasting, therefore,

mothers should continuously be encouraged to go for antenatal care services in their countries.

Children who were delivered at home compared to children who were delivered at a health facility were found to have a higher risk of co-existence of the three dimensions. Since mothers who deliver at home do not receive any expert nutritional advice from a qualified health practitioner[37], the children of such mothers are at higher risk of having these conditions because of poor and/ or inadequate dietary practices. This finding shows that facility delivery may help reduce the risk of co-existence of stunting, underweight, and wasting among children under 5. Therefore, mothers should regularly be educated on the need to opt for facility delivery because of its positive implications on children's growth.

The risk of co-existence of the three dimensions was higher among children whose mothers were poor and had middle wealth status compared to those whose mothers were rich. Usually, mothers who have an average income may lack the financial capacity to feed themselves and their children properly and adequately[3,17,36], increasing the children's risk of being stunted, underweight or wasted. Likewise, mothers from poor and middle wealth quintiles may not have access to quality nutritional products and health care systems[36,40], making their children more susceptible to having all three nutritional conditions. This finding implies that women from poor economic backgrounds should be assisted with nutritional products and services to facilitate the reduction in the risks of the co-existence of stunting, underweight, and wasting among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no access to media compared to those whose mothers had access to media. Since many people are educated about proper nutritional practices through the mass media[10,11], mothers who have no access to the media may lack certain important nutritional information they need. This information gap could increase children's risk of having all three nutritional conditions through improper dietary practices from their mothers. For instance, mothers' access to appropriate information from the media would help them decide on which proper diets or food commodities are readily available on market for their children. More pragmatic ways of reaching mothers who have no access to media are encouraged. Regular outreach or sensitization programs to target women without access to media for example could help in reducing the risks of the co-existence of stunting, underweight, and wasting among children under 5 years.

Children whose mothers had unimproved toilet facilities were found to have a higher risk of co-existence of the three dimensions of child undernutrition compared to those whose mothers had improved toilet facilities. Insanitary or unhygienic toilet conditions may increase mother-child-environment interactions that may result in increased exposure to childhood diseases and other opportunistic infections (e.g., diarrhoeal episodes, fever) either through consumption of contaminated foods, drinking water or poor environmental sanitation[21]. These conditions have been shown to cause growth retardation in children. Government and non-governmental organizations should support the provision of improved household toilet facilities for poorer communities to help minimize the risks of the co-existence of child undernutrition indicators.

Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having the co-existence of the three dimensions compared to those from Angola. On the other

hand, countries such as Benin, Cameroon, Congo, Gabon, Ghana, Guinea, Kenya, Lesotho, Malawi, Senegal, Zambia, Uganda, Tanzania, Sierra Leone, Zimbabwe, and South Africa had a lower risk among their children having co-existence of the three undernutrition dimensions. The sub-regional and country-specific variations in socio-economic, agro-ecological and geographical characteristics may strongly influence the nutritional status of children because of inadequate food supplies, limited access to arable land for agriculture, unfavourable climatic conditions (e.g., desertification), rapid population growth, and increasing cost of living may determine food access, availability and production in studied countries in SSA[41,42]. Governmental priorities should intensify efforts to minimize the risk of co-existence of stunting, underweight, and wasting among children under age 5 with sound socio-economic and sustainable human capital development.

Conclusions and implications

The study investigated the risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The study found that the prevalence of co-existence of stunting, underweight, and wasting ranged from 0.58 % in the Gambia to 12.14% in Benin. The study also found that the prevalence of co-existence of stunting, underweight, and wasting was high in Western Africa (41.78%) but low in Southern Africa (5.3%). The significant findings show that the disadvantaged have more risks of the co-existence of stunting, underweight, and wasting among under 5 children in selected SSA countries. These findings demonstrate the urgent need for consideration of the co-existence of stunting, wasting and underweight among under-five children in policy design and programming of interventions to eradicate child malnutrition in SSA. In the short-term, national-level policies and interventions needs to be well-tailored considering the compositional characteristics including child's age, sex, birth size; maternal education, working status, place of delivery, antenatal visit; and household's wealth status, access to media and improved toilet facility are required. For instance, such programs could be geared towards improving females' access to education, reducing unemployment, expanding access to the media and using it to promote education on the need for antenatal care. In the long-term, regional policies and coordinated interventions among governments of SSA countries need to be designed to address the disparate prevalence of the co-existence of stunting, wasting and underweight in under-five children across the four geographic regions. The implementation of these at the local-level should consider rural-urban differences in the prevalence of the condition and the risk factors elicited.

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Ethics Approval and consent to participate

This study used secondary data from the DHS Program. Since we neither interacted directly nor indirectly with the study participants, there was no need for ethical approval. Details on the ethical considerations of the DHS Program could found at https://dhsprogram.com/methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm.

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References

1. Amare ZY, Ahmed ME, Mehari AB. Determinants of nutritional status among children under age 5 in Ethiopia: further analysis of the 2016 Ethiopia demographic and health survey. *Global Health* 2019;15(1):1–11.
2. Anin SK, Saaka M, Fischer F, Kraemer A. Association between Infant and Young Child Feeding (IYCF) Indicators and the Nutritional Status of Children (6–23 Months) in Northern Ghana. Nutrients *2020;* 12, 2565. https://doi.org/10.3390/nu12092565
3. Madiba S, Chelule PK, Mokgatle MM. Attending informal preschools and daycare centers is a risk factor for underweight, stunting and wasting in children under the age of five years in underprivileged communities in South Africa. *International Journal of Environmental Research and Public Health* 2019; 16(14), 2589.
4. Yalew BM, Amsalu F, Bikes D. Prevalence and factors associated with stunting, underweight and wasting: a community based cross sectional study among children age 6-59 months at Lalibela Town, Northern Ethiopia. *J Nutr Disorders Ther* 2014; 4(147), 2161-0509.
5. WHO. Nutrition Landscape Information System (NLIS) Country Profile Indicators: Interpretation Guide; World Health Organization: Geneva, Switzerland, 2010.
6. Akombi BJ, Agho KE, Hall JJ, Wali N, Renzaho A, Merom D. Stunting, wasting and underweight in sub-Saharan Africa: a systematic review. *International Journal of Environmental Research and Public Health* 2017; 14(8), 863.
7. WHO. Global nutrition targets 2025: policy brief series (WHO/NMH/NHD/14.2). Geneva: World Health Organization; 2014. https://apps.who.int/iris/bitstream/handle/10665/149018/WHO_NMH_NHD_14.2_eng.pdf
8. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, Ezzati M, Grantham-McGregor S, Katz J, Martorell R, Uauy R, Maternal and Child Nutrition Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries. *The lancet* 2013; 382(9890), 427-451.

9. World Health Organization. Levels and trends in child malnutrition: key findings of the 2019 edition (No. WHO/NMH/NHD/19.20). World Health Organization. 2019.
10. De Onis M, Onyango A, Borghi E, Siyam A, Blössner M, Lutter C. Worldwide implementation of the WHO child growth standards. *Public Health Nutrition* 2012; 15(9), 1603-1610.
11. De Onis M, Blössner M, Borghi E. Prevalence and trends of stunting among pre-school children, 1990–2020. *Public Health Nutrition* 2012; 15(1), 142-148.
12. World Health Organization. Community-based management of severe acute malnutrition: a joint statement by the World Health Organization, the World Food Programme, the United Nations System Standing Committee on Nutrition and the United Nations Children's Fund. 2007.
13. UNICEF. Levels and trends in child malnutrition, United Nations Children's fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and trends in child malnutrition: key findings of the 2019 edition of the joint child malnutrition estimates. Geneva: World Health Organization; 2019 Licence: CC BY-NC-SA 3.0 IGO; 2019.
14. Central Statistical Agency (CSA)[Ethiopia] and ICF. Ethiopia demographic and health survey, Addis Ababa, Ethiopia and Calverton, Maryland, USA. 2016.
15. Yaya S, Uthman OA, Ekholuenetale M, Bishwajit G, Adjiwanou V. Effects of birth spacing on adverse childhood health outcomes: evidence from 34 countries in sub-Saharan Africa. *J Matern & Neonatal Med* 2020;33(20):3501–8.
16. Armah FA, Ekumah B, Yawson DO, Odoi JO, Afitiri A, Nyieku FE, et al. Predictive Probabilities of Access to Clean Cooking: Evidence from the Demographic and Health Surveys in 31 Countries in Sub-Saharan Africa. 2019;12(3):320–2.
17. Mamabolo RL, Alberts M, Steyn NP, Delemarre-van de Waal HA, Levitt NS. Prevalence and determinants of stunting and overweight in 3-year-old black South African children residing in the Central Region of Limpopo Province, South Africa. *Public Health Nutrition* 2005; 8(5), 501-508.
18. Novignon J, Aboagye E, Agyemang OS, Aryeetey G. Socioeconomic-related inequalities in child malnutrition: evidence from the Ghana multiple indicator cluster survey. *Health Economics Review* 2015; 5(1), 1-11.
19. Khara T, Mwangome M, Ngari M, Dolan C. Children concurrently wasted and stunted: A meta-analysis of prevalence data of children 6–59 months from 84 countries. Maternal & child nutrition. 2018 Apr;14(2):e12516.
20. Boah M, Azupogo F, Amporfro DA, Abada LA. The epidemiology of undernutrition and its determinants in children under five years in Ghana. Plos one. 2019 Jul 31;14(7):e0219665.
21. Khan RE, Raza MA. Determinants of malnutrition in Indian children: new evidence from IDHS through CIAF. Quality & Quantity. 2016 Jan 1;50(1):299-316.
22. Angood C, Khara T, Dolan C, Berkley JA, WaSt Technical Interest Group. Research priorities on the relationship between wasting and stunting. PloS one. 2016 May 9;11(5):e0153221.
23. Corsi DJ, Neuman M, Finlay JE, Subramanian SV. Demographic and health surveys: a profile. *International Journal of Epidemiology* 2012; 41(6), 1602-1613.

24. Aliaga A, Ruilin R. Cluster optimal sample size for demographic and health surveys. In 7th International Conference on Teaching Statistics–ICOTS (Vol. 7, pp. 2-7). 2006.

[dataset] 25. DHS. DHS data source https://dhsprogram.com/data/available-datasets.cfm

26. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, Strobe Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. International journal of surgery. 2014; 12(12), 1495-1499.
27. Collins J, Ward BM, Snow P, Kippen S, Judd F. Compositional, Contextual, and Collective Community Factors in Mental Health and Well-Being in Australian Rural Communities. *Qualitative Health Research* 2017; 27(5), 677–687. https://doi.org/10.1177/1049732315625195
28. Pol LG, Thomas RK. The demography of health and health care. Springer Science & Business Media. 2001.
29. Armah FA, Ekumah B, Yawson DO, Odoi JO, Afitiri AR, Nyieku F.E. Access to improved water and sanitation in sub-Saharan Africa in a quarter century. *Heliyon* 2018; 4(11), e00931. https://doi.org/10.1016/j.heliyon.2018.e00931
30. Ross CE, Mirowsky J. Neighborhood socioeconomic status and health: context or composition? *City & Community* 2008; 7(2), 163–179.
31. Amegah AK, Boachie J, Näyhä S, Jaakkola JJK. Association of biomass fuel use with reduced body weight of adult Ghanaian women. *J Expo Sci Environ Epidemiol* 2019;1.
32. Alemayehu M, Tinsae F, Haileslassie K, Seid O, Gebregziabher G, Yebyo H. Undernutrition status and associated factors in under-5 children, in Tigray, Northern Ethiopia. *Nutrition* 2015; 31(7-8), 964-970.
33. Mya KS, Kyaw AT, Tun T. Feeding practices and nutritional status of children age 6-23 months in Myanmar: A secondary analysis of the 2015-16 Demographic and Health Survey. *PloS one* 2019; 14(1), e0209044.
34. Bork KA, Diallo A. Boys are more stunted than girls from early infancy to 3 years of age in rural Senegal. *The Journal of Nutrition* 2017; 147(5), 940-947.
35. Tumilowicz A, Habicht JP, Pelto G, Pelletier DL. Gender perceptions predict sex differences in growth patterns of indigenous Guatemalan infants and young children. *The American Journal of Clinical Nutrition* 2015; 102(5), 1249-1258.
36. Mukabutera A, Thomson DR, Hedt-Gauthier BL, Basinga P, Nyirazinyoye L, Murray M. Risk factors associated with underweight status in children under five: an analysis of the 2010 Rwanda Demographic Health Survey (RDHS). *BMC Nutrition* 2016; 2(1), 1-12.
37. Oyekale AS. Factors explaining acute malnutrition among under-five children in Sub-Sahara Africa (SSA). *Life Sci J* 2012; 9, 2101-7.
38. Keats A. Women's schooling, fertility, and child health outcomes: Evidence from Uganda's free primary education program. *Journal of Development Economics* 2018; 135, 142-159.
39. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Poor nutrition status and associated feeding practices among HIV-positive children in a food secure region in Tanzania: a call for tailored nutrition training. *PloS one* 2014; 9(5), e98308.

40. Iannotti LL, Dulience SJL, Green J, Joseph S, François J, Antenor ML, ... Nickerson NM. Linear growth increased in young children in an urban slum of Haiti: a randomized controlled trial of a lipid-based nutrient supplement. *The American Journal of Clinical Nutrition* 2014; 99(1), 198-208.
41. Lopriore C, Muehlhoff E. Food security and nutrition trends in West Africa—Challenges and the way forward. In Proceedings of the 2nd International Workshop on Food-based Approaches for a Healthy Nutrition, Ouagadougou, Burkina. 2003; 23–28.
42. Salami A, Kamara AB, Brixiova Z. Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities; African Development Bank: Tunis, Tunisia, 2010.

Figures

Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

Tables

Table 1: Distribution of the relevant variables and characteristics of under-five children in SSA

Variable	%	Variable	%
Age of child		Urbanicity	
0	30.87	Urban	33.21
1	28.42	Rural	66.79
2	20.22	Place of delivery	
3	12.40	Home	31.33
4	8.09	Health facility	67.51
Sex of child		Other	1.16
Male	50.47	Wealth status	
Female	49.53	Poor	42.41
Birth order		Middle	20.28
1	19.52	Rich	37.31
2 to 4	48.09	Age of household head	
5 and above	32.39	Young-adults	43.08
Perceived size at birth		Middle-aged adults	43.76
Large	33.71	Old-aged adults	13.16
Average	49.74	Sex of household head	
Small	16.54	Male	79.77
Mother's characteristics		Female	20.23
Maternal age		Access to electricity	
15-19	7.13	No	69.20
20-49	92.87	Yes	30.80
Educational attainment			
No education	41.82	Type of toilet facility	
Primary	31.26	Improved	42.47
Secondary	23.82	Unimproved	57.53
Higher	3.10	Source of drinking water	
Working status		Improved	65.63
No	35.49	Unimproved	34.37
Yes	64.51	Type of cooking fuel	
Antenatal visits during pregnancy		Clean	89.76
No	10.76	Unclean	10.24
Yes	89.24	Geographic region	
Postnatal check within 2 months		Western	41.78
No	58.49	Eastern	32.84
Yes	41.51	Central	20.08
Access to media (tv/radio/newspaper)		South Africa	5.30
Yes	35.33		
No	64.67		(N=127,487)

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600 Table 2: Prevalence and association of the co-existence of stunting, underweight and wasting with independent variables

Variable	Co-existed Weighted % (95% CI)	Variable	Co-existed Weighted % (95% CI)	Variable	Co-existed Weighted % (95% CI)
Age of child (p<0.001)		**Place of delivery (p<0.001)**		**Country (p<0.001)**	
<1	1.75 (1.6-1.9)	Home	4.36 (4.2-4.6)	Angola	2.46 (2.1-2.8)
1	4.44 (4.2-4.7	Health facility	1.96 (1.9-2.1)	Benin	2.04 (1.8-2.2)
2	3.01 (2.8-3.2)	Other	2.45 (1.7-3.3)	Burkina Faso	5.31 (4.9-5.8)
3	1.62 (1.4-1.8)	**Wealth status (p<0.001)**		Burundi	3.76 (3.2-4.4)
4	1.33 (1.1-1.6)	Poor	3.46 (3.3-3.6)	Cameroon	1.27 (0.9-1.7)
Sex of child (p<0.001)		Middle	2.74 (2.5-2.9)	Chad	5.86 (5.2-6.5)
Male	3.43 (3.3-3.6)	Rich	1.86 (1.7-2.0)	Comoros	1.98 (1.3-2.9)
Female	1.99 (1.9-2.1)	**Age of household head (p = 0.2760**		Congo	0.98 (0.7-1.5)
Birth order (p<0.001)		Young-adults	2.65 (2.5-2.8)	Cote d'Ivoire	2.28 (1.7-3.0)
1	2.25 (2.1-2.4)	Middle-aged adults	2.76 (2.6-2.9)	DR Congo	2.66 (2.2-3.2)
2 to 4	2.56 (2.4-2.7)	Old-aged adults	2.8 (2.6-3.1)	Ethiopia	3.64 (3.2-4.1)
5 and above	3.23 (3.1-3.4)	**Sex of household head (p<0.001)**		Gabon	0.63 (0.3-1.0)
Perceived size at birth (p<0.001)		Male	2.82 (2.7-2.9)	The Gambia	3.61 (2.4-5.2)
Large	1.78 (1.7-1.9)	Female	2.33 (2.1-2.5)	Ghana	1.37 (0.9-2.0)
Average	2.6 (2.5-2.7)	**Access to electricity (p<0.001)**		Guinea	2.26 (1.7-2.9)
Small	4.98 (4.7-5.3)	No	3.21 (3.1-3.3)	Kenya	0.94 (0.7-1.2)

Maternal age (P = 0.080)		Yes	1.61 (1.5-1.7)	Lesotho	0.86 (0.7-1.0)
		Access to media			
15-19	2.78 (2.5-3.1)	**(tv/radio/newspaper) (p<0.001)**		Liberia	2.37 (1.7-3.1)
20-49	2.71 (2.6-2.8)	Yes	2.14 (2.0-2.2)	Malawi	1.03 (0.7-1.4)
Educational attainment					
(p<0.001)		No	3.78 (3.6-4.0)	Mali	3.62 (2.5-4.1)
No education	4.19 (4.0-4.4)	**Type of toilet facility (p<0.001)**		Namibia	1.99 (1.2-3.1)
Primary	2.09 (2.0-2.2)	Improved	1.76 (1.6-1.9)	Nigeria	4.1 (3.7-4.6)
Secondary	1.22 (1.1-1.3)	Unimproved	3.43 (3.3-3.6)	Rwanda	6.17 (5.5-6.9)
		Source of drinking water			
Higher	0.66 (0.4-1.0)	**(p<0.001)**		Senegal	2.43 (1.8-3.2)
				Sierra	
Working status (p<0.001)		Improved	2.54 (2.4-2.6)	Leone	1.94 (1.4-2.5)
				South	
No	3.13 (3.0-3.3)	Unimproved	3.06 (2.9-3.2)	Africa	0.18 (0.02-0.8)
Yes	2.48 (2.4-2.6)	**Type of cooking fuel (p<0.001)**		Tanzania	1.86 (2.1-3.5)
Antenatal visits during					
pregnancy (p<0.001)		Clean	0.98 (0.8.2-1.2)	Togo	2.72 (2.1-3.4)
No	5.41 (5.0-5.8)	Unclean	2.92 (2.8-3.0)	Uganda	1.2 (0.8-1.7)
Yes	2.39 (2.3-2.5)	**Urbanicity (p<0.001)**		Zambia	1.22 (1.0-1.5)
Postnatal check within 2					
months (p<0.001)		Urban	1.73 (1.6-1.9)	Zimbabwe	0.78 (0.5-1.1)
No	2.93 (2.8-3.1)	Rural	3.21 (3.1-3.3)	**Geographic region (p<0.0010**	
Yes	2.42 (2.3-2.6)			Western	3.11 (3.0-2.3)
				Eastern	2.43 (2.3-2.6)
				Central	2.87 (2.7-3.1)
				South	
				Africa	0.88 (0.66-1.1)

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603 **Table 3: Multinomial regression showing risk factors of co-existence of stunting, underweight, and wasting**

Variable	Base outcome (Ref: Normal)					
	Single and two dimensions			Co-existence of three-dimensions		
	RRR	95% CI		RRR	95% CI	
Age of child (Ref:0)						
1	2.008***	1.93	2.089	3.714***	3.319	4.156
2	2.624***	2.514	2.739	2.827***	2.48	3.222
3	2.122***	2.018	2.231	1.464***	1.227	1.748
4	1.504***	1.417	1.597	1.051	0.84	1.315
Sex of child (Ref: Male)						
Female	0.752***	0.731	0.775	0.468***	0.429	0.51
Birth order (Ref: 1)						
2	0.938**	0.896	0.981	1.002	0.875	1.146
5 and above	0.969	0.92	1.021	0.995	0.858	1.155
Perceived size at birth (Ref: Large)						
Average	1.32***	1.276	1.365	1.756***	1.574	1.958
Small	1.931***	1.846	2.02	3.818***	3.383	4.308
Maternal age (Ref: 15-19)						
20-49	0.834***	0.78	0.891	0.881	0.735	1.056
Educational attainment (Ref: Higher)						
No education	2.624***	2.305	2.987	3.291***	1.961	5.522
Primary	2.189***	1.927	2.487	2.381***	1.417	4.001
Secondary	1.751***	1.545	1.985	1.617	0.971	2.691
Working status (Ref: Yes)						
No	1.018	0.984	1.053	1.195***	1.086	1.314
Antenatal visits during pregnancy (Ref: Yes)						<0.001
No	1.139***	1.079	1.201	1.364***	1.208	1.541
Postnatal check within 2 months (Ref: Yes)						
No	0.98	0.946	1.015	0.977	0.879	1.086
Place of delivery (Ref: Health facility)						

Home	1.183***	1.137	1.23	1.372***	1.232	1.529
Other	1.046	0.912	1.201	1.047	0.71	1.543
Wealth status (Ref: Rich)						
Poor	1.297***	1.235	1.361	1.408***	1.235	1.605
Middle	1.195***	1.138	1.254	1.214**	1.054	1.397
Age of household head (Ref: Young-adult)						
Middle-aged adults	0.954**	0.921	0.987	1.01	0.913	1.118
Old-aged adults	0.974	0.93	1.021	1.065	0.936	1.213
Sex of household head (Ref: Male)						
Female	0.977	0.94	1.015	1.035	0.925	1.159
Access to media (tv/radio/newspaper) (Ref: Yes)						
No	1.079***	1.042	1.117	1.255***	1.144	1.377
Access to electricity (Ref: Yes)						
No	1.136***	1.083	1.191	1.062	0.922	1.225
Type of toilet facility (Ref: Improved)						
Unimproved	1.027	0.991	1.065	1.158**	1.032	1.3
Source of drinking water (Ref: Improved)						
Unimproved	0.959**	0.928	0.99	0.968	0.885	1.058
Type of cooking fuel (Ref: Clean)						
Unclean	1.177***	1.089	1.271	1.316	0.97	1.787
Urbanicity (Ref: Urban)						
Rural	1.05**	1.006	1.095	0.943	0.832	1.069

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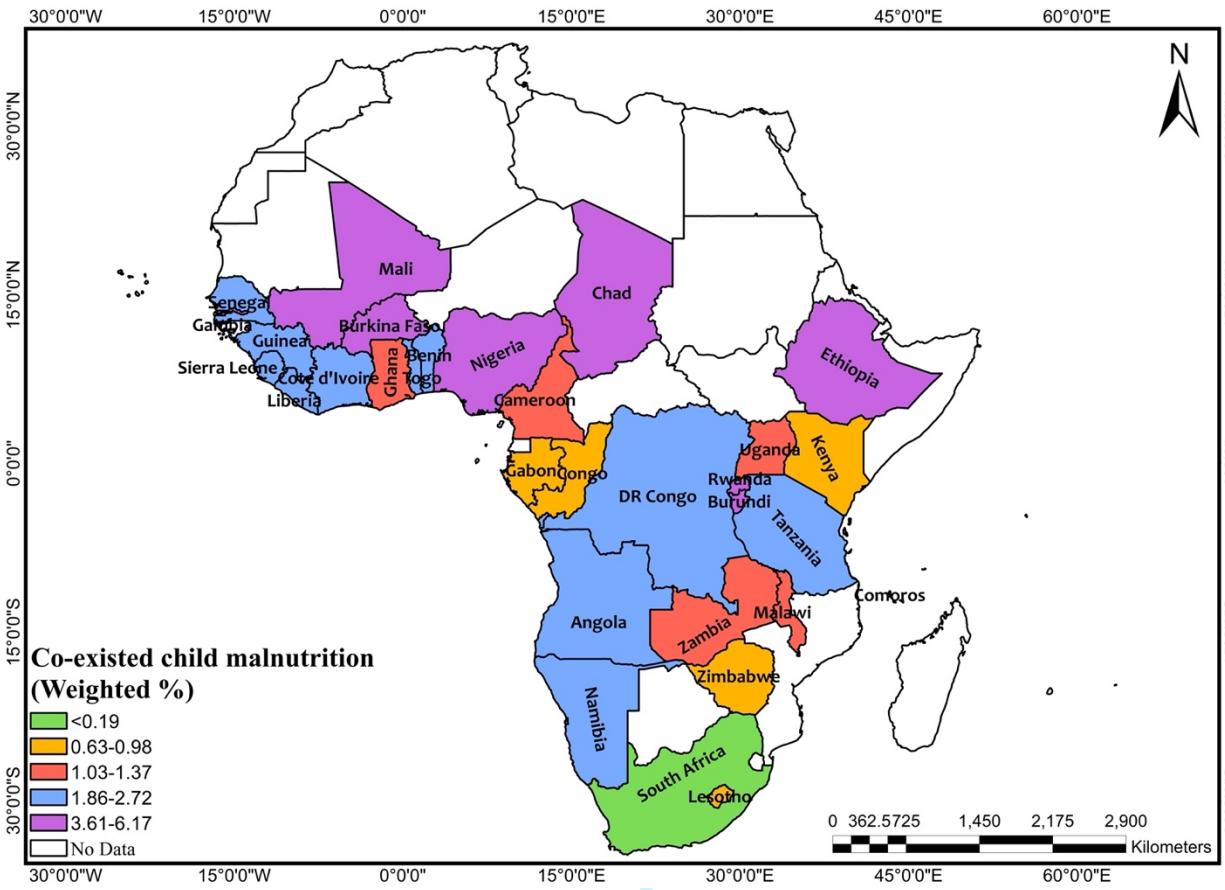

Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

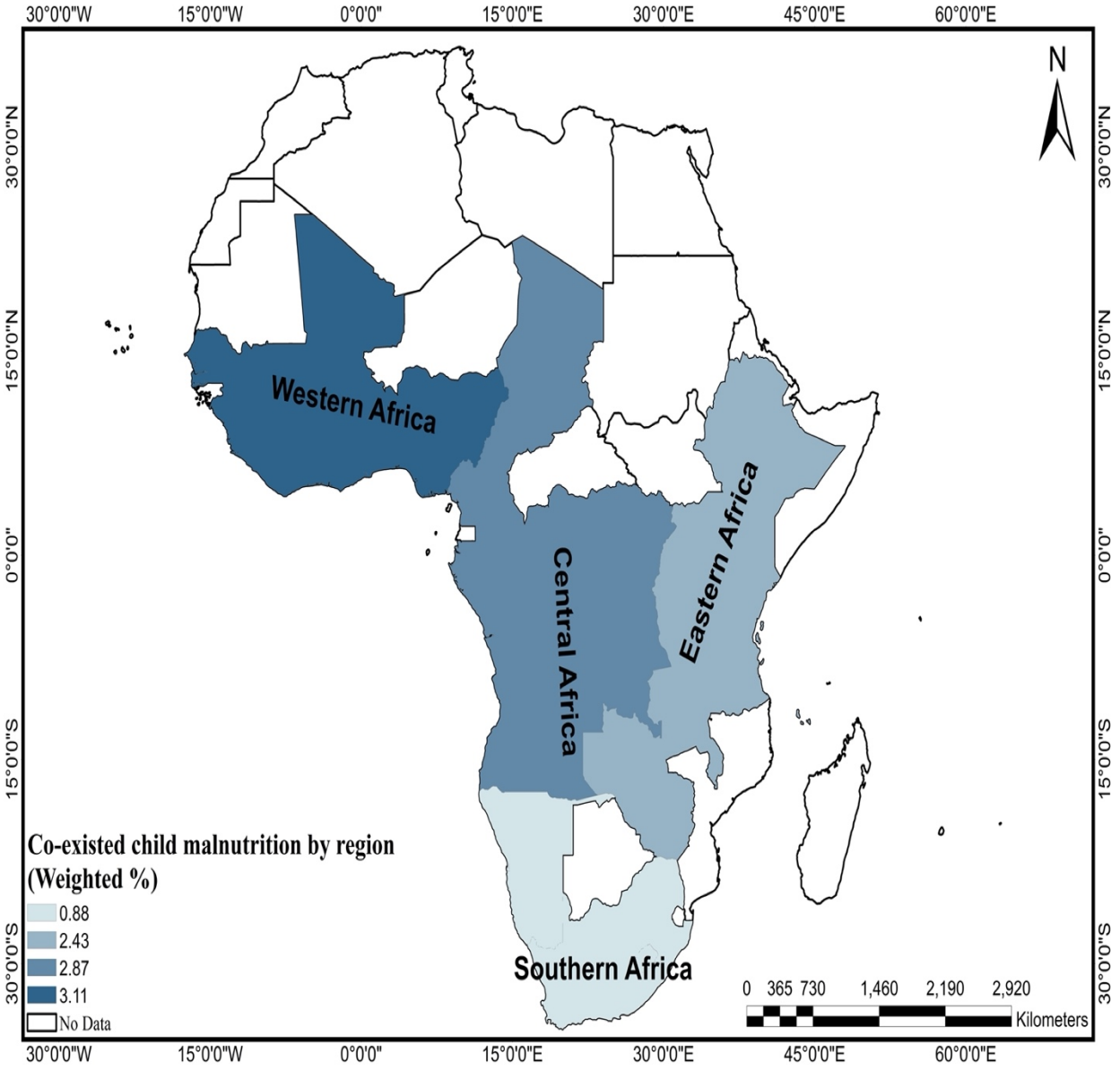

Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

Supplementary Tables

Appendix 1: Distribution of sample by country

Country	Survey year	n	%
Angola	2015-16	7,318	5.74
Benin	2017-18	15,473	12.14
Burkina Faso	2010	8,908	6.99
Burundi	2016-17	4,172	3.27
Cameroon	2018	2,911	2.28
Chad	2014-2015	5,999	4.71
Comoros	2012	1,320	1.03
Congo	2013	2,609	2.05
Cote d'Ivoire	2011-12	2,174	1.71
Congo DR	2013-14	4,806	3.77
Ethiopia	2016	6,573	5.16
Gabon	2012	1,960	1.54
Gambia	2013	743	0.58
Ghana	2014	1,896	1.49
Guinea	2018	2,237	1.75
Kenya	2014	6,066	4.76
Lesotho	2014	1,012	0.79
Liberia	2013	1,946	1.53
Malawi	2015-16	4,027	3.16
Mali	2018	5,653	4.43
Namibia	2013	905	0.71
Nigeria	2018	7,379	5.79
Rwanda	2014-15	4,408	3.46
Senegal	2010-11	1,944	1.52
Sierra Leone	2019	2,689	2.11
South Africa	2016	855	0.67
Tanzania	2015-16	6,061	4.75
Togo	2013-14	2,220	1.74
Uganda	2016	2,891	2.27
Zambia	2018	6,347	4.98
Zimbabwe	2015	3,987	3.13

Appendix 2: Multicollinearity diagnosis				
Variable	VIF	SQRT VIF	Tolerance	R-Squared
Age of child	1.05	1.02	0.9547	0.0453
Sex of child	1.01	1	0.9948	0.0052
Birth order	1.36	1.17	0.7366	0.2634
Perceived size at birth	1.02	1.01	0.9798	0.0202
Age at child birth	1.22	1.1	0.8224	0.1776
Educational attainment	1.51	1.23	0.664	0.336
Working status	1.07	1.03	0.9357	0.0643
Antenatal visits during pregnancy	1.25	1.12	0.7976	0.2024
Postnatal check within 2 months	1.1	1.05	0.9098	0.0902
Place of delivery	1.31	1.15	0.7617	0.2383
Wealth status	1.8	1.34	0.5554	0.4446
Age of household head	1.05	1.02	0.9546	0.0454
Sex of household head	1.03	1.02	0.9702	0.0298
Access to media (tv/radio/newspaper)	1.26	1.12	0.7913	0.2087
Access to electricity	1.71	1.31	0.5837	0.4163
Type of toilet facility	1.35	1.16	0.7404	0.2596
Source of drinking water	1.09	1.04	0.9191	0.0809
Type of cooking fuel	1.31	1.14	0.7653	0.2347
Urbanicity	1.58	1.26	0.6319	0.3681
Country	1.17	1.08	0.8579	0.1421
Mean VIF	1.26			

Appendix 3: **Country-level risk of co-existence of stunting, wasting, and underweight**

	Base outcome (Ref: Normal)					
	Single and two dimensions			Co-existence of three-dimensions		
	RRR	95% CI		RRR	95% CI	
Country (Ref: Angola)						
Benin	0.651***	0.598	0.708	0.625***	0.489	0.798
Burkina Faso	0.952	0.866	1.046	1.946***	1.526	2.481
Burundi	1.580***	1.424	1.753	2.049***	1.545	2.718
Cameroon	0.669***	0.593	0.756	0.398***	0.261	0.609
Chad	0.910	0.823	1.007	1.505**	1.184	1.913
Comoros	0.883	0.745	1.046	0.656	0.378	1.138
Congo	0.674***	0.580	0.783	0.472**	0.279	0.800
Cote d'Ivoire	0.734***	0.638	0.844	0.739	0.492	1.109
DR Congo	1.229***	1.100	1.373	1.351	0.988	1.847
Ethiopia	0.810***	0.726	0.904	0.813	0.604	1.095
Gabon	0.495***	0.415	0.59	0.319**	0.128	0.796
Gambia	0.732**	0.603	0.889	1.001	0.618	1.620
Ghana	0.453***	0.386	0.531	0.545**	0.346	0.857
Guinea	0.798***	0.705	0.904	0.726	0.509	1.036
Kenya	0.553***	0.498	0.615	0.321***	0.230	0.449
Lesotho	0.777**	0.654	0.924	0.369***	0.177	0.772
Liberia	0.658***	0.565	0.768	0.776	0.484	1.243
Malawi	0.794***	0.708	0.889	0.447***	0.291	0.687
Mali	0.600***	0.541	0.664	1.006	0.769	1.316
Namibia	0.680***	0.568	0.815	0.849	0.505	1.426
Nigeria	0.953	0.868	1.046	1.527**	1.183	1.972
Rwanda	1.059	0.954	1.176	1.991***	1.541	2.571
Senegal	0.660***	0.572	0.761	0.643*	0.434	0.952
Sierra Leone	0.641***	0.567	0.725	0.656*	0.447	0.963
South Africa	0.788*	0.634	0.979	0.108***	0.033	0.352
Tanzania	0.772***	0.699	0.851	0.699**	0.512	0.954
Togo	0.557***	0.490	0.633	0.838	0.590	1.190
Uganda	0.627***	0.556	0.708	0.421***	0.278	0.637
Zambia	0.904*	0.818	0.998	0.519***	0.366	0.736
Zimbabwe	0.693***	0.620	0.775	0.344***	0.214	0.554

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Risk factors associated with the co-existence of stunting, underweight, and wasting in children under five from 31 sub-Saharan African countries

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ABSTRACT

Objective: This study investigated the risk factors associated with the co-existence of stunting, underweight, and wasting among children under age five in sub-Saharan Africa (SSA).

Design: Data of 127,487 under-five children from 31 sub-Saharan African countries were pooled from the Demographic and Health Surveys collected between 2010 and 2019. We examined the risk of co-existence of undernutrition using multinomial logistic regression models, with results presented as relative risk ratios (RRR).

Setting: Thirty-one sub-Saharan African countries.

Participants: Children under age five

Outcome measures: The outcome variables were three child anthropometrics: stunting (height-for-age z-scores); underweight (weight-for-age z-scores); and wasting (weight-for-height z-scores).

Results: The prevalence of co-existence of stunting, underweight, and wasting varied across countries and sub-regions, with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting as Benin (12.14%) and Gambia (0.58%) respectively. The risk of co-existence of the three undernutrition dimensions was higher among children aged 1 year (RRR=3.714; 95%CI 3.319-4.156) compared to those aged 0. The risk of co-existence of the three dimensions was lower among female children (RRR=0.468 95% CI 0.420-0.51) but higher for those with small size at birth (RRR=3.818; CI 3.383-4.308), those whose mothers had no education (RRR=3.291; 95% CI 1.961-5.522), not working (RRR=1.195; 95% CI 1.086-1.314), had no antenatal visits during pregnancy (RRR=1.364; 95% CI 1.20-1.541), children delivered at home (RRR=1.372; CI 1.232-1.529), those from poor households (RRR=1.408; 95% CI 1.235-1.605), those whose mothers had no access to media (RRR=1.255; 95% CI 1.144-1.377), and living in households with an unimproved toilet facility (RRR=1.158; 95% CI 1.032-1.300).

Conclusions: Findings suggest the urgent need for consideration of the co-existence of stunting, wasting and underweight among under-five children in policy design and programming of interventions to eradicate child malnutrition in SSA. In the short-term, national-level policies and interventions need to be well-tailored considering the compositional characteristics.

Keywords: co-existence; stunting; underweight; wasting; children under five; sub-Saharan Africa

Strength and Limitations

- Nationally representative data of under-five children from 31 SSA countries were analysed.
- Multinomial logistic regression was used to assess the risks factors to the co-existence of stunting, wasting and underweight in children.
- A broad range of potential risk factors a various levels were considered.
- Also, the DHS employs cross-sectional designs which restrict causality on the noted outcomes.
- Self-reported variables used are susceptible to biases from recall and other social desirability issues.

INTRODUCTION

Undernutrition among children under 5 years remains a major public health problem across many low-and middle-income countries[1-3]. Factors such as insufficient food intake, diarrhoea, recurring infections, poor sanitation practices, and low parental education have been identified as significant contributors to the high prevalence of undernutrition during childhood[1,4,5]. Despite the numerous interventions rolled out to address childhood undernutrition especially in sub-Saharan Africa where the phenomenon is quite pervasive, the progress seems to be insignificant[6,7]. For example, a study reported that child undernutrition accounted for nearly half (45%) of the child mortality rate in low-and middle-income countries[8]. Aside from that, it was reported in 2018 that about 149 million and 49 million children under age 5 were stunted and wasted respectively[9].

Three main indicators that are often used to represent undernutrition are underweight or low weight for age, stunting or low height for age, and wasting or low weight for height[2,10-12]. Among the three indicators of undernutrition, stunting has been identified as the problem with the greatest magnitude among under 5 children in developing countries[2,3]. Even though the prevalence of stunting in sub-Saharan Africa is declining, it is worth noting that it is still above 30%[13] which is undeniably high. Research also indicates that the country-specific prevalence of stunting, underweight and wasting is still high[2,3]. For instance, in Ethiopia, the prevalence of wasting and stunting were 10% and 38% respectively[14]. Additionally, the prevalence of stunting, underweight and wasting among children in South Africa were 35.8%, 20.5%, and 17.2%[3]. Likewise, Anin et al.[2] reported 33.2%, 14.1%, 27% and 2.6% of prevalence in stunting, wasting, underweight and overweight among infants (6-23 months) across Northern Ghana.

Previous studies have investigated the compositional and contextual risk factors associated with either stunting, underweight or wasting among children under 5 years and found the age of a child, sex of the child, child's size at birth, mother's age during childbirth, mother's educational level, birth order, place of residence and mother's body mass index (BMI) as associated factors[1-3,15,16]. Other studies also found a significant linkage between household wealth quintile and maternal short stature, and nutritional status of children under 5[17,18]. Regarding the sex of a child, for example, female children were found to be less likely to suffer from stunting compared to males[1,3].

Apart from studies that have examined the factors associated with either stunting, underweight, and wasting, some scholars have begun looking at predictors of the co-existence of any two or three of the indicators of malnutrition. A study in 84 countries that examined the prevalence and predictors of co-existence of stunting and wasting found sex and age of children as significant predictors[19]. Other studies in Ghana[20] and India[21] also examined the co-existence of stunting, underweight, and wasting and found birth interval, birth weight, dietary diversity, place of delivery, wealth index, mother's BMI, mother's educational level, and partners' educational level as associated factors. The need to examine the co-existence of stunting, underweight and wasting is important because not much work has been done on that subject and hence children who concurrently suffer from stunting, underweight, and wasting are less likely to be reached in malnutrition prevention programmes, especially in SSA. For instance, some scholars have indicated that despite evidence that wasting and stunting are global public health problems that frequently co-exist, they are usually separated in terms of policy, guidance, programming

and financing[22]. This creates a gap in the literature that needs to be filled. Despite the detrimental consequences of undernutrition on the health and wellbeing of children under 5 in SSA, studies utilizing current, and nationally representative data to investigate the risk factors associated with the co-existence of stunting, underweight, and wasting among this age group are absent in the literature. Studies presenting empirical analyses of the co-existence of these three indicators of child undernutrition in SSA are absent in extant literature making it difficult for policymakers and nutritional experts to provide up-to-date trends with appropriate strategies to curb the situation in the sub-region. This research lag presents a void in extant literature which this study seeks to bridge. Therefore, the study investigated the risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from the Demographic Health Survey (DHS) conducted in 31 countries between 2010 and 2019. The findings of the study could contribute to the formulation of policies and interventions to respond to the nutritional needs of children under 5 years and also suggest pragmatic ways of reducing undernutrition among children in the sub-region.

METHODS

Data Source

The dataset included 127,487 children under the age of 5 years from 31 sub-Saharan African countries (Figure 1) were pooled from the most current Demographic and Health Surveys (DHS) conducted between 2010 and 2019 (Appendix 1). Specifically, the data were pooled from the children's files in each of the countries. The DHS Program has conducted over 400 surveys in over 90 developing countries around the world since 1984 every five years[23]. The program implements cross-sectional surveys to gather nationally-representative data, analyze and disseminate accurate information on important demographic and health indicators spanning population, nutrition, and diseases. For all surveys, standardized protocols designed for each target group including children, women, and men at the household level are employed to allow for cross-national comparisons. Stratified two-stage sampling involves first, the listing of enumeration areas and selection of clusters, and then a random selection of households in each cluster. The detailed sampling method can be found in a previous study[24]. The dataset is freely available for download at: https://dhsprogram.com/data/available-datasets.cfm[25]. The Strengthening Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed in writing the manuscript[26].

Study Variables

Outcome Variable

The outcome variable considered in this study is derived from three child anthropometric variables including stunting (height-for-age z-scores); underweight (weight-for-age z-scores) and wasting (weight-for-height z-scores). The DHS (2021) specifies categorization for each of these variables following the WHO child growth standard. Each of the three variables we coded into "0" for "Normal" and "1" for "Stunting", "underweight" and "Wasting" respectively.

These three variables were then added to generate the outcome variable "Co-existed undernutrition" with scores (discrete) ranging from 0 to 3 where 0 implies "Normal", that is, children with none of the three conditions; 1 implies "Single burden", that is, the child suffers from one of the three conditions; 2 indicates that child suffers from "Two burdens" out of the three; and 3 shows "Co-existed", that is, the child suffers from all three conditions of undernutrition. For parsimony, children who suffered from "Single burden" and those who suffered from "Two burdens" were added resulting in the variable "Co-existed undernutrition" with three response categories: 0=Normal; 1=One or two burdens; and 3=co-existed.

Independent Variables

Several risk factors spanning compositional to contextual factors have been associated with child undernutrition. The relevant biosocial characteristics and sociocultural factors related to the child, mother, household head and the household together form compositional factors[27,28]. Factors that describe location or "place-based" variables are contextual factors[20,27,29,30]. The relevant compositional factors considered include the age of the child; sex of the child; birth order of child; perceived size at birth; mother's age; educational attainment; working status; antenatal visits during pregnancy; postnatal check within 2 months; and place of delivery. At the household level, relevant variables included are the wealth status; the age of household head; sex of household head (male and female); access to electricity; and access to media which was derived from the three variables "access to television", "radio" and "newspaper". Household basic needs include the type of toilet facility (re-coded into "improved" and unimproved"[29]; source of drinking water (re-coded as "improved" and "unimproved"[29], and type of household cooking fuel (re-coded into "clean" and "unclean" [29,31] are also considered. The contextual factors considered are urbanicity and the country of origin of the participant.

Data Analyses

The statistical analysis of the data was performed using the Stata SE software version 14.2. The "svyset" command was first used to declare the data as survey data to prevent the potential effects of the complex sampling techniques on the analyses. The sample weight variable in the DHS was used to provide weighted samples in the analyses. To understand the distributions of the variables, the data were summarized and presented in tables using descriptive statistics (frequencies, weighted percentages, and 95% confidence intervals (CIs) of percentages). We further integrated the data into a GIS environment and presented the distribution of key variables across the study countries and geographic regions in map images (Figure 1 and Figure 2). This approach enhances the visualization of the data and understanding of the context of the study. The associations between the co-existence of undernutrition and each of the risk factors considered were assessed using the chi-square test of independence, with results presented in a contingency table. The risk factors as independent variables were then subjected to collinearity diagnosis tests, including Variance Inflation Factors (VIF), Square VIF, Tolerance, and R-squared. This was done to ascertain whether the independent variables were actually "independent", that is, are not correlated with one another and will not share variance in the outcome variable. Results from the multicollinearity diagnoses test (See Appendix 2) show that the variables were not correlated (Mean VIF=1.26; Maximum VIF=1.71; Minimum VIF=1.02). To determine

the risk factors associated with the co-existence of undernutrition, a multinomial regression model was implemented. All statistical tests were conducted at $p<0.05$.

Ethical Approval

This study used secondary data from the DHS Program. Since we neither interacted directly nor indirectly with the study participants, there was no need for ethical approval. Details on the ethical considerations of the DHS Program could be found at https://dhsprogram.com/methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm.

Patient and public involvement

Patients and the public were not involved in the design and conduct of this research

Results

Distribution of sample characteristics

The study included a total of 127,487 under-five children. It is found that most (30.87%) of the children were less than a year (Table 1). With regards to sex, both males and females constituted approximately half of the sample. A majority of the children (92.87%) were born to mothers aged between 20 to 49years while only 7.13% were born to mothers aged 15 to 19years. In terms of education, most (41.82%) of the children were born to mothers with no formal education. Only 3.10% of the children were born to a mother with a higher level of educational attainment. Further, 42.1% of the children were born in poor households while 37.21% were born in rich households. More than half (57.53%) of the children lived in a household with unimproved toilet facilities. However, most (65.63%) of the children lived in households with access to improved drinking water sources. Similarly, a majority (89.76%) of the children lived in households using clean cooking fuel (Table 1).

As shown in Appendix 2, the prevalence of co-existence of stunting, underweight, and underweight varied across countries and sub-regions, with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting as Rwanda (6.17%) and South Africa (0.18%) respectively (Figure 1). In terms of sub-region, the highest prevalence of co-existence of stunting, underweight, and wasting was observed in Western Africa (3.11%) and the lowest prevalence in Southern Africa (0.88%) (Figure 2).

Significant associations between all the independent variables and co-existence of stunting, wasting, and underweight, except maternal age and age of household head, were identified (Table 2).

Table 1

Figure 1

Figure 2

Table 2

Risk factors of the co-existence of stunting, wasting and underweight

Table 3 shows the results of the multinomial regression analysis of the risk factors of co-existence of dimensions of undernutrition (stunting, underweight, and wasting) among

children under five years in the SSA. Age of child, size of the child at birth, sex of the child, birth order, educational level, maternal age, ANC attendance, place of delivery, source of drinking water, sex of household head, wealth index, access to electricity and place of residence were associated with one or two dimensions of undernutrition. See Appendix 3 for country-level risk of co-existence of stunting, wasting, and underweight.

Regarding the co-existence of the three dimensions of undernutrition (stunting, underweight, and wasting), age of the child, sex of the child, perceived birth size, maternal educational attainment, working status, antenatal visits during pregnancy, place of delivery, wealth status, access to media, and type of toilet facility were found to be significant risk factors (Table 3).

Table 3

DISCUSSION

The study investigated the risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The study found that the countries with the highest and lowest prevalence of co-existence of stunting, underweight, and wasting were Benin and Gambia respectively. In terms of geographic region, the highest prevalence of co-existence of stunting, underweight, and wasting was observed in Western Africa and the lowest prevalence in Southern Africa. The disparities in the prevalence among the countries and geographical regions could be attributed to the nutritional practices and beliefs practised in the countries and geographical regions. Differences in the health policies provided by governments in the various countries could also account for the disparities noted. This finding implies that countries that have high prevalence should take critical lessons from the countries that are doing well regarding the implementation of nutritional policies and interventions (e.g., increasing dietary supplementation, increasing dietary diversity) that target the reduction of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa[2].

Similar to previous studies[1,3], this study found that children aged 1 year, 2 years, and 3 years were at greater risk of having co-existence of all the three forms of undernutrition compared to those aged 0. A plausible reason for this finding could be that as children grow their energy needs also increase[1], increasing their risk of having all three nutritional conditions. Alternatively, since these nutritional conditions may manifest after long durations of improper nutritional practices or undernutrition[1,3], older children may be at higher risk of having all three nutritional conditions. The finding suggests that complementary foods given to children as they grow are inadequate. To reduce the risk of co-existence of stunting, underweight, and wasting among under 5 children, the health sectors in the various countries should invest heavily in providing adequate complementary feeding to this category of children.

Corroborating the findings of other studies[1,3,32,33], this study also found that children who were females were less likely to have a co-existence of the three dimensions of undernutrition compared to their male counterparts. An acceptable explanation for this finding could be the biological variations in morbidity between males and females at that young age[3]. It is also possible that since male children have higher birth weight compared to females, they require more energy[1,34], which increases the risk of males having all three

nutritional conditions. Moreover, male children are perceived to be hungrier than females, therefore breastfeeding alone could be insufficient or inadequate[3,35], increasing their susceptibility to having the three nutritional conditions. The finding suggests that male children should be given critical attention in the development and implementation of nutritional programs (e.g., dietary supplementation) to mitigate the co-existence of stunting, underweight, and wasting among these male children under 5 years.

The study found that the risk of co-existence of the three dimensions of undernutrition was higher among children with the average size at birth and small size at birth compared to children with large size at birth. It has been proven that undernutrition in children is partly influenced by maternal nutrition practices. Hence, mothers' appropriate nutritional behaviours during the prenatal and postnatal periods are key to improving child growth. Conversely, maternal undernutrition causes low maternal BMI, which in turn affects the foetus to poor development often associated with a small birth size and low birth weight[1,3,21,36]. This finding indicates that mothers of children under 5 should continuously be educated on the best nutritional practices such as exclusive breastfeeding, complementary feeding, and dietary supplementation. These strategies will help ameliorate the risk of acquiring health conditions associated with undernutrition among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no education and primary education compared to those whose mothers had higher education. Mothers who have attained higher education are better informed about improved childcare practices[37], are more empowered to make health decisions[38], practice good personal hygiene[38], are more likely to use the health facility[39], proper feeding practices[36] and childcare in times of illness[36,40]. This finding suggests that mothers with no formal or little education are neglected in nutritional programs that help to eliminate stunting, underweight, and wasting. Hence, they should be given the needed consideration to deal with this persistent health issue.

This study also found that the risk of co-existence of the three dimensions was higher among children whose mothers were not working compared to those whose mothers were working. Women's employment status indicates their ability to afford proper nutritional products and health care services[36,40]. Therefore, if mothers are not employed, the children become highly susceptible or vulnerable because mothers are unlikely to meet their nutritional needs or requirements. Mothers with children under 5 with such disadvantaged backgrounds should be given subsidies on children's nutritional products and perhaps, free access to health care services by governmental and non-governmental organizations. This step will be significant in reducing the risks of the co-existence of stunting, underweight, and wasting among children under 5 years.

The risk of co-existence of the three dimensions was higher among children whose mothers had no antenatal visits during pregnancy compared to those whose mothers had antenatal visits during pregnancy. Specifically, mothers who attend antenatal services are usually educated on the best practices of nutrition and general healthcare, which hitherto would not be known by these mothers[38]. Therefore, mothers who did not have antenatal visits may lack some knowledge about proper nutritional practices, increasing their children's risk of having these undernutrition-related challenges. Regular antenatal visits could reduce children's risk of stunting, being underweight, and wasting, therefore,

mothers should continuously be encouraged to go for antenatal care services in their countries.

Children who were delivered at home compared to children who were delivered at a health facility were found to have a higher risk of co-existence of the three dimensions. Since mothers who deliver at home do not receive any expert nutritional advice from a qualified health practitioner[37], the children of such mothers are at higher risk of having these conditions because of poor and/ or inadequate dietary practices. This finding shows that facility delivery may help reduce the risk of co-existence of stunting, underweight, and wasting among children under 5. Therefore, mothers should regularly be educated on the need to opt for facility delivery because of its positive implications on children's growth.

The risk of co-existence of the three dimensions was higher among children whose mothers were poor and had middle wealth status compared to those whose mothers were rich. Usually, mothers who have an average income may lack the financial capacity to feed themselves and their children properly and adequately[3,17,36], increasing the children's risk of being stunted, underweight or wasted. Likewise, mothers from poor and middle wealth quintiles may not have access to quality nutritional products and health care systems[36,40], making their children more susceptible to having all three nutritional conditions. This finding implies that women from poor economic backgrounds should be assisted with nutritional products and services to facilitate the reduction in the risks of the co-existence of stunting, underweight, and wasting among children under 5.

The risk of co-existence of the three dimensions was higher among children whose mothers had no access to media compared to those whose mothers had access to media. Since many people are educated about proper nutritional practices through the mass media[10,11], mothers who have no access to the media may lack certain important nutritional information they need. This information gap could increase children's risk of having all three nutritional conditions through improper dietary practices from their mothers. For instance, mothers' access to appropriate information from the media would help them decide on which proper diets or food commodities are readily available on market for their children. More pragmatic ways of reaching mothers who have no access to media are encouraged. Regular outreach or sensitization programs to target women without access to media for example could help in reducing the risks of the co-existence of stunting, underweight, and wasting among children under 5 years.

Children whose mothers had unimproved toilet facilities were found to have a higher risk of co-existence of the three dimensions of child undernutrition compared to those whose mothers had improved toilet facilities. Insanitary or unhygienic toilet conditions may increase mother-child-environment interactions that may result in increased exposure to childhood diseases and other opportunistic infections (e.g., diarrhoeal episodes, fever) either through consumption of contaminated foods, drinking water or poor environmental sanitation[21]. These conditions have been shown to cause growth retardation in children. Government and non-governmental organizations should support the provision of improved household toilet facilities for poorer communities to help minimize the risks of the co-existence of child undernutrition indicators.

Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having the co-existence of the three dimensions compared to those from Angola. On the other

hand, countries such as Benin, Cameroon, Congo, Gabon, Ghana, Guinea, Kenya, Lesotho, Malawi, Senegal, Zambia, Uganda, Tanzania, Sierra Leone, Zimbabwe, and South Africa had a lower risk among their children having co-existence of the three undernutrition dimensions. The sub-regional and country-specific variations in socio-economic, agro-ecological and geographical characteristics may strongly influence the nutritional status of children because of inadequate food supplies, limited access to arable land for agriculture, unfavourable climatic conditions (e.g., desertification), rapid population growth, and increasing cost of living may determine food access, availability and production in studied countries in SSA[41,42]. Governmental priorities should intensify efforts to minimize the risk of co-existence of stunting, underweight, and wasting among children under age 5 with sound socio-economic and sustainable human capital development.

Strength and limitations

The use of relative large nationally representative data of under-five children from 31 SSA countries is the main strength of the study. We also employed rigorous statistical analytical techniques to analyse the data. A broad range of potential risk factors a various levels were considered in our analysis. Despite these, the DHS employs cross-sectional designs which restrict causality on the noted outcomes. Self-reported variables used are, therefore, susceptible to biases from recall and other social desirability issues. The surveys were also conducted in different years.

Conclusions and implications

The study investigated the risk factors of the co-existence of stunting, underweight, and wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The study found that the prevalence of co-existence of stunting, underweight, and wasting ranged from 0.58 % in the Gambia to 12.14% in Benin. The study also found that the prevalence of co-existence of stunting, underweight, and wasting was high in Western Africa (41.78%) but low in Southern Africa (5.3%). The significant findings show that the disadvantaged have more risks of the co-existence of stunting, underweight, and wasting among under 5 children in selected SSA countries. These findings demonstrate the urgent need for consideration of the co-existence of stunting, wasting and underweight among under-five children in policy design and programming of interventions to eradicate child malnutrition in SSA. In the short-term, national-level policies and interventions needs to be well-tailored considering the compositional characteristics including child's age, sex, birth size; maternal education, working status, place of delivery, antenatal visit; and household's wealth status, access to media and improved toilet facility are required. For instance, such programs could be geared towards improving females' access to education, reducing unemployment, expanding access to the media and using it to promote education on the need for antenatal care. In the long-term, regional policies and coordinated interventions among governments of SSA countries need to be designed to address the disparate prevalence of the co-existence of stunting, wasting and underweight in under-five children across the four geographic regions. The implementation of these at the local level should consider rural-urban differences in the prevalence of the condition and the risk factors elicited.

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Competing interests: None

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

Ethics approval and consent to participate

This study used secondary data from the DHS Program. Since we neither interacted directly nor indirectly with the study participants, there was no need for ethical approval. Details on the ethical considerations of the DHS Program could be found at https://dhsprogram.com/methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm.

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References

1. Amare ZY, Ahmed ME, Mehari AB. Determinants of nutritional status among children under age 5 in Ethiopia: further analysis of the 2016 Ethiopia demographic and health survey. *Global Health* 2019;15(1):1–11.
2. Anin SK, Saaka M, Fischer F, Kraemer A. Association between Infant and Young Child Feeding (IYCF) Indicators and the Nutritional Status of Children (6–23 Months) in Northern Ghana. Nutrients *2020;* 12, 2565. https://doi.org/10.3390/nu12092565
3. Madiba S, Chelule PK, Mokgatle MM. Attending informal preschools and daycare centers is a risk factor for underweight, stunting and wasting in children under the age of five years in underprivileged communities in South Africa. *International Journal of Environmental Research and Public Health* 2019; 16(14), 2589.
4. Yalew BM, Amsalu F, Bikes D. Prevalence and factors associated with stunting, underweight and wasting: a community based cross sectional study among children age 6-59 months at Lalibela Town, Northern Ethiopia. *J Nutr Disorders Ther* 2014; 4(147), 2161-0509.
5. WHO. Nutrition Landscape Information System (NLIS) Country Profile Indicators: Interpretation Guide; World Health Organization: Geneva, Switzerland, 2010.

6. Akombi BJ, Agho KE, Hall JJ, Wali N, Renzaho A, Merom D. Stunting, wasting and underweight in sub-Saharan Africa: a systematic review. *International Journal of Environmental Research and Public Health* 2017; 14(8), 863.
7. WHO. Global nutrition targets 2025: policy brief series (WHO/NMH/NHD/14.2). Geneva: World Health Organization; 2014. https://apps.who.int/iris/bitstream/handle/10665/149018/WHO_NMH_NHD_14.2_eng.pdf
8. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, Ezzati M, Grantham-McGregor S, Katz J, Martorell R, Uauy R, Maternal and Child Nutrition Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries. *The lancet* 2013; 382(9890), 427-451.
9. World Health Organization. Levels and trends in child malnutrition: key findings of the 2019 edition (No. WHO/NMH/NHD/19.20). World Health Organization. 2019.
10. De Onis M, Onyango A, Borghi E, Siyam A, Blössner M, Lutter C. Worldwide implementation of the WHO child growth standards. *Public Health Nutrition* 2012; 15(9), 1603-1610.
11. De Onis M, Blössner M, Borghi E. Prevalence and trends of stunting among pre-school children, 1990–2020. *Public Health Nutrition* 2012; 15(1), 142-148.
12. World Health Organization. Community-based management of severe acute malnutrition: a joint statement by the World Health Organization, the World Food Programme, the United Nations System Standing Committee on Nutrition and the United Nations Children's Fund. 2007.
13. UNICEF. Levels and trends in child malnutrition, United Nations Children's fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and trends in child malnutrition: key findings of the 2019 edition of the joint child malnutrition estimates. Geneva: World Health Organization; 2019 Licence: CC BY-NC-SA 3.0 IGO; 2019.
14. Central Statistical Agency (CSA)[Ethiopia] and ICF. Ethiopia demographic and health survey, Addis Ababa, Ethiopia and Calverton, Maryland, USA. 2016.
15. Yaya S, Uthman OA, Ekholuenetale M, Bishwajit G, Adjiwanou V. Effects of birth spacing on adverse childhood health outcomes: evidence from 34 countries in sub-Saharan Africa. *J Matern & Neonatal Med* 2020;33(20):3501–8.
16. Armah FA, Ekumah B, Yawson DO, Odoi JO, Afitiri A, Nyieku FE, et al. Predictive Probabilities of Access to Clean Cooking: Evidence from the Demographic and Health Surveys in 31 Countries in Sub-Saharan Africa. 2019;12(3):320–2.
17. Mamabolo RL, Alberts M, Steyn NP, Delemarre-van de Waal HA, Levitt NS. Prevalence and determinants of stunting and overweight in 3-year-old black South African children residing in the Central Region of Limpopo Province, South Africa. *Public Health Nutrition* 2005; 8(5), 501-508.
18. Novignon J, Aboagye E, Agyemang OS, Aryeetey G. Socioeconomic-related inequalities in child malnutrition: evidence from the Ghana multiple indicator cluster survey. *Health Economics Review* 2015; 5(1), 1-11.
19. Khara T, Mwangome M, Ngari M, Dolan C. Children concurrently wasted and stunted: A meta-analysis of prevalence data of children 6–59 months from 84 countries. Maternal & child nutrition. 2018 Apr;14(2):e12516.

20. Boah M, Azupogo F, Amporfro DA, Abada LA. The epidemiology of undernutrition and its determinants in children under five years in Ghana. Plos one. 2019 Jul 31;14(7):e0219665.
21. Khan RE, Raza MA. Determinants of malnutrition in Indian children: new evidence from IDHS through CIAF. Quality & Quantity. 2016 Jan 1;50(1):299-316.
22. Angood C, Khara T, Dolan C, Berkley JA, WaSt Technical Interest Group. Research priorities on the relationship between wasting and stunting. PloS one. 2016 May 9;11(5):e0153221.
23. Corsi DJ, Neuman M, Finlay JE, Subramanian SV. Demographic and health surveys: a profile. *International Journal of Epidemiology* 2012; 41(6), 1602-1613.
24. Aliaga A, Ruilin R. Cluster optimal sample size for demographic and health surveys. In 7th International Conference on Teaching Statistics–ICOTS (Vol. 7, pp. 2-7). 2006.
[dataset] 25. DHS. DHS data source https://dhsprogram.com/data/available-datasets.cfm
26. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, Strobe Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. International journal of surgery. 2014; 12(12), 1495-1499.
27. Collins J, Ward BM, Snow P, Kippen S, Judd F. Compositional, Contextual, and Collective Community Factors in Mental Health and Well-Being in Australian Rural Communities. *Qualitative Health Research* 2017; 27(5), 677–687. https://doi.org/10.1177/1049732315625195
28. Pol LG, Thomas RK. The demography of health and health care. Springer Science & Business Media. 2001.
29. Armah FA, Ekumah B, Yawson DO, Odoi JO, Afitiri AR, Nyieku F.E. Access to improved water and sanitation in sub-Saharan Africa in a quarter century. *Heliyon* 2018; 4(11), e00931. https://doi.org/10.1016/j.heliyon.2018.e00931
30. Ross CE, Mirowsky J. Neighborhood socioeconomic status and health: context or composition? *City & Community* 2008; 7(2), 163–179.
31. Amegah AK, Boachie J, Näyhä S, Jaakkola JJK. Association of biomass fuel use with reduced body weight of adult Ghanaian women. *J Expo Sci Environ Epidemiol* 2019;1.
32. Alemayehu M, Tinsae F, Haileslassie K, Seid O, Gebregziabher G, Yebyo H. Undernutrition status and associated factors in under-5 children, in Tigray, Northern Ethiopia. *Nutrition* 2015; 31(7-8), 964-970.
33. Mya KS, Kyaw AT, Tun T. Feeding practices and nutritional status of children age 6-23 months in Myanmar: A secondary analysis of the 2015-16 Demographic and Health Survey. *PloS one* 2019; 14(1), e0209044.
34. Bork KA, Diallo A. Boys are more stunted than girls from early infancy to 3 years of age in rural Senegal. *The Journal of Nutrition* 2017; 147(5), 940-947.
35. Tumilowicz A, Habicht JP, Pelto G, Pelletier DL. Gender perceptions predict sex differences in growth patterns of indigenous Guatemalan infants and young children. *The American Journal of Clinical Nutrition* 2015; 102(5), 1249-1258.
36. Mukabutera A, Thomson DR, Hedt-Gauthier BL, Basinga P, Nyirazinyoye L, Murray M. Risk factors associated with underweight status in children under five: an

analysis of the 2010 Rwanda Demographic Health Survey (RDHS). *BMC Nutrition* 2016; 2(1), 1-12.

37. Oyekale AS. Factors explaining acute malnutrition among under-five children in Sub-Sahara Africa (SSA). *Life Sci J* 2012; 9, 2101-7.
38. Keats A. Women's schooling, fertility, and child health outcomes: Evidence from Uganda's free primary education program. *Journal of Development Economics* 2018; 135, 142-159.
39. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Poor nutrition status and associated feeding practices among HIV-positive children in a food secure region in Tanzania: a call for tailored nutrition training. *PloS one* 2014; 9(5), e98308.
40. Iannotti LL, Dulience SJL, Green J, Joseph S, François J, Antenor ML, ... Nickerson NM. Linear growth increased in young children in an urban slum of Haiti: a randomized controlled trial of a lipid-based nutrient supplement. *The American Journal of Clinical Nutrition* 2014; 99(1), 198-208.
41. Lopriore C, Muehlhoff E. Food security and nutrition trends in West Africa—Challenges and the way forward. In Proceedings of the 2nd International Workshop on Food-based Approaches for a Healthy Nutrition, Ouagadougou, Burkina. 2003; 23–28.
42. Salami A, Kamara AB, Brixiova Z. Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities; African Development Bank: Tunis, Tunisia, 2010.

Figures

Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

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607 Tables

608 **Table 1: Distribution of the relevant variables and characteristics of under-five children in SSA**

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Variable	%	Variable	%
Age of child		Urbanicity	
0	30.87	Urban	33.21
1	28.42	Rural	66.79
2	20.22	Place of delivery	
3	12.40	Home	31.33
4	8.09	Health facility	67.51
Sex of child		Other	1.16
Male	50.47	Wealth status	
Female	49.53	Poor	42.41
Birth order		Middle	20.28
1	19.52	Rich	37.31
2 to 4	48.09	Age of household head	
5 and above	32.39	Young-adults	43.08
Perceived size at birth		Middle-aged adults	43.76
Large	33.71	Old-aged adults	13.16
Average	49.74	Sex of household head	
Small	16.54	Male	79.77
Mother's characteristics		Female	20.23
Maternal age		Access to electricity	
15-19	7.13	No	69.20
20-49	92.87	Yes	30.80
Educational attainment			
No education	41.82	Type of toilet facility	
Primary	31.26	Improved	42.47
Secondary	23.82	Unimproved	57.53
Higher	3.10	Source of drinking water	
Working status		Improved	65.63
No	35.49	Unimproved	34.37
Yes	64.51	Type of cooking fuel	
Antenatal visits during pregnancy		Clean	89.76
No	10.76	Unclean	10.24
Yes	89.24	Geographic region	
Postnatal check within 2 months		Western	41.78
No	58.49	Eastern	32.84
Yes	41.51	Central	20.08
Access to media (tv/radio/newspaper)		South Africa	5.30
Yes	35.33		
No	64.67		(N=127,487)

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Table 2: Prevalence and association of the co-existence of stunting, underweight and wasting with independent variables

Variable	Co-existed Weighted % (95% CI)	Variable	Co-existed Weighted % (95% CI)	Variable	Co-existed Weighted % (95% CI)
Age of child (p<0.001)		**Place of delivery (p<0.001)**		**Country (p<0.001)**	
<1	1.75 (1.6-1.9)	Home	4.36 (4.2-4.6)	Angola	2.46 (2.1-2.8)
1	4.44 (4.2-4.7	Health facility	1.96 (1.9-2.1)	Benin	2.04 (1.8-2.2)
2	3.01 (2.8-3.2)	Other	2.45 (1.7-3.3)	Burkina Faso	5.31 (4.9-5.8)
3	1.62 (1.4-1.8)	**Wealth status (p<0.001)**		Burundi	3.76 (3.2-4.4)
4	1.33 (1.1-1.6)	Poor	3.46 (3.3-3.6)	Cameroon	1.27 (0.9-1.7)
Sex of child (p<0.001)		Middle	2.74 (2.5-2.9)	Chad	5.86 (5.2-6.5)
Male	3.43 (3.3-3.6)	Rich	1.86 (1.7-2.0)	Comoros	1.98 (1.3-2.9)
Female	1.99 (1.9-2.1)	**Age of household head (p = 0.2760**		Congo	0.98 (0.7-1.5)
Birth order (p<0.001)		Young-adults	2.65 (2.5-2.8)	Cote d'Ivoire	2.28 (1.7-3.0)
1	2.25 (2.1-2.4)	Middle-aged adults	2.76 (2.6-2.9)	DR Congo	2.66 (2.2-3.2)
2 to 4	2.56 (2.4-2.7)	Old-aged adults	2.8 (2.6-3.1)	Ethiopia	3.64 (3.2-4.1)
5 and above	3.23 (3.1-3.4)	**Sex of household head (p<0.001)**		Gabon	0.63 (0.3-1.0)
Perceived size at birth (p<0.001)		Male	2.82 (2.7-2.9)	The Gambia	3.61 (2.4-5.2)
Large	1.78 (1.7-1.9)	Female	2.33 (2.1-2.5)	Ghana	1.37 (0.9-2.0)
Average	2.6 (2.5-2.7)	**Access to electricity (p<0.001)**		Guinea	2.26 (1.7-2.9)
Small	4.98 (4.7-5.3)	No	3.21 (3.1-3.3)	Kenya	0.94 (0.7-1.2)

Maternal age (P = 0.080)		Yes	1.61 (1.5-1.7)	Lesotho	0.86 (0.7-1.0)
		Access to media			
15-19	2.78 (2.5-3.1)	**(tv/radio/newspaper) (p<0.001)**		Liberia	2.37 (1.7-3.1)
20-49	2.71 (2.6-2.8)	Yes	2.14 (2.0-2.2)	Malawi	1.03 (0.7-1.4)
Educational attainment					
(p<0.001)		No	3.78 (3.6-4.0)	Mali	3.62 (2.5-4.1)
No education	4.19 (4.0-4.4)	**Type of toilet facility (p<0.001)**		Namibia	1.99 (1.2-3.1)
Primary	2.09 (2.0-2.2)	Improved	1.76 (1.6-1.9)	Nigeria	4.1 (3.7-4.6)
Secondary	1.22 (1.1-1.3)	Unimproved	3.43 (3.3-3.6)	Rwanda	6.17 (5.5-6.9)
		Source of drinking water			
Higher	0.66 (0.4-1.0)	**(p<0.001)**		Senegal	2.43 (1.8-3.2)
				Sierra	
Working status (p<0.001)		Improved	2.54 (2.4-2.6)	Leone	1.94 (1.4-2.5)
				South	
No	3.13 (3.0-3.3)	Unimproved	3.06 (2.9-3.2)	Africa	0.18 (0.02-0.8)
Yes	2.48 (2.4-2.6)	**Type of cooking fuel (p<0.001)**		Tanzania	1.86 (2.1-3.5)
Antenatal visits during					
pregnancy (p<0.001)		Clean	0.98 (0.8.2-1.2)	Togo	2.72 (2.1-3.4)
No	5.41 (5.0-5.8)	Unclean	2.92 (2.8-3.0)	Uganda	1.2 (0.8-1.7)
Yes	2.39 (2.3-2.5)	**Urbanicity (p<0.001)**		Zambia	1.22 (1.0-1.5)
Postnatal check within 2					
months (p<0.001)		Urban	1.73 (1.6-1.9)	Zimbabwe	0.78 (0.5-1.1)
No	2.93 (2.8-3.1)	Rural	3.21 (3.1-3.3)	**Geographic region (p<0.0010)**	
Yes	2.42 (2.3-2.6)			Western	3.11 (3.0-2.3)
				Eastern	2.43 (2.3-2.6)
				Central	2.87 (2.7-3.1)
				South	
				Africa	0.88 (0.66-1.1)

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Table 3: Multinomial regression showing risk factors of co-existence of stunting, underweight, and wasting

Variable	Base outcome (Ref: Normal)					
	Single and two dimensions			Co-existence of three-dimensions		
	RRR	95% CI		RRR	95% CI	
Age of child (Ref:0)						
1	2.008***	1.93	2.089	3.714***	3.319	4.156
2	2.624***	2.514	2.739	2.827***	2.48	3.222
3	2.122***	2.018	2.231	1.464***	1.227	1.748
4	1.504***	1.417	1.597	1.051	0.84	1.315
Sex of child (Ref: Male)						
Female	0.752***	0.731	0.775	0.468***	0.429	0.51
Birth order (Ref: 1)						
2	0.938**	0.896	0.981	1.002	0.875	1.146
5 and above	0.969	0.92	1.021	0.995	0.858	1.155
Perceived size at birth (Ref: Large)						
Average	1.32***	1.276	1.365	1.756***	1.574	1.958
Small	1.931***	1.846	2.02	3.818***	3.383	4.308
Maternal age (Ref: 15-19)						
20-49	0.834***	0.78	0.891	0.881	0.735	1.056
Educational attainment (Ref: Higher)						
No education	2.624***	2.305	2.987	3.291***	1.961	5.522
Primary	2.189***	1.927	2.487	2.381***	1.417	4.001
Secondary	1.751***	1.545	1.985	1.617	0.971	2.691
Working status (Ref: Yes)						
No	1.018	0.984	1.053	1.195***	1.086	1.314
Antenatal visits during pregnancy (Ref: Yes)						<0.001
No	1.139***	1.079	1.201	1.364***	1.208	1.541
Postnatal check within 2 months (Ref: Yes)						
No	0.98	0.946	1.015	0.977	0.879	1.086
Place of delivery (Ref: Health facility)						

Home	1.183***	1.137	1.23	1.372***	1.232	1.529
Other	1.046	0.912	1.201	1.047	0.71	1.543
Wealth status (Ref: Rich)						
Poor	1.297***	1.235	1.361	1.408***	1.235	1.605
Middle	1.195***	1.138	1.254	1.214**	1.054	1.397
Age of household head (Ref: Young-adult)						
Middle-aged adults	0.954**	0.921	0.987	1.01	0.913	1.118
Old-aged adults	0.974	0.93	1.021	1.065	0.936	1.213
Sex of household head (Ref: Male)						
Female	0.977	0.94	1.015	1.035	0.925	1.159
Access to media (tv/radio/newspaper) (Ref: Yes)						
No	1.079***	1.042	1.117	1.255***	1.144	1.377
Access to electricity (Ref: Yes)						
No	1.136***	1.083	1.191	1.062	0.922	1.225
Type of toilet facility (Ref: Improved)						
Unimproved	1.027	0.991	1.065	1.158**	1.032	1.300
Source of drinking water (Ref: Improved)						
Unimproved	0.959**	0.928	0.99	0.968	0.885	1.058
Type of cooking fuel (Ref: Clean)						
Unclean	1.177***	1.089	1.271	1.316	0.97	1.787
Urbanicity (Ref: Urban)						
Rural	1.05**	1.006	1.095	0.943	0.832	1.069

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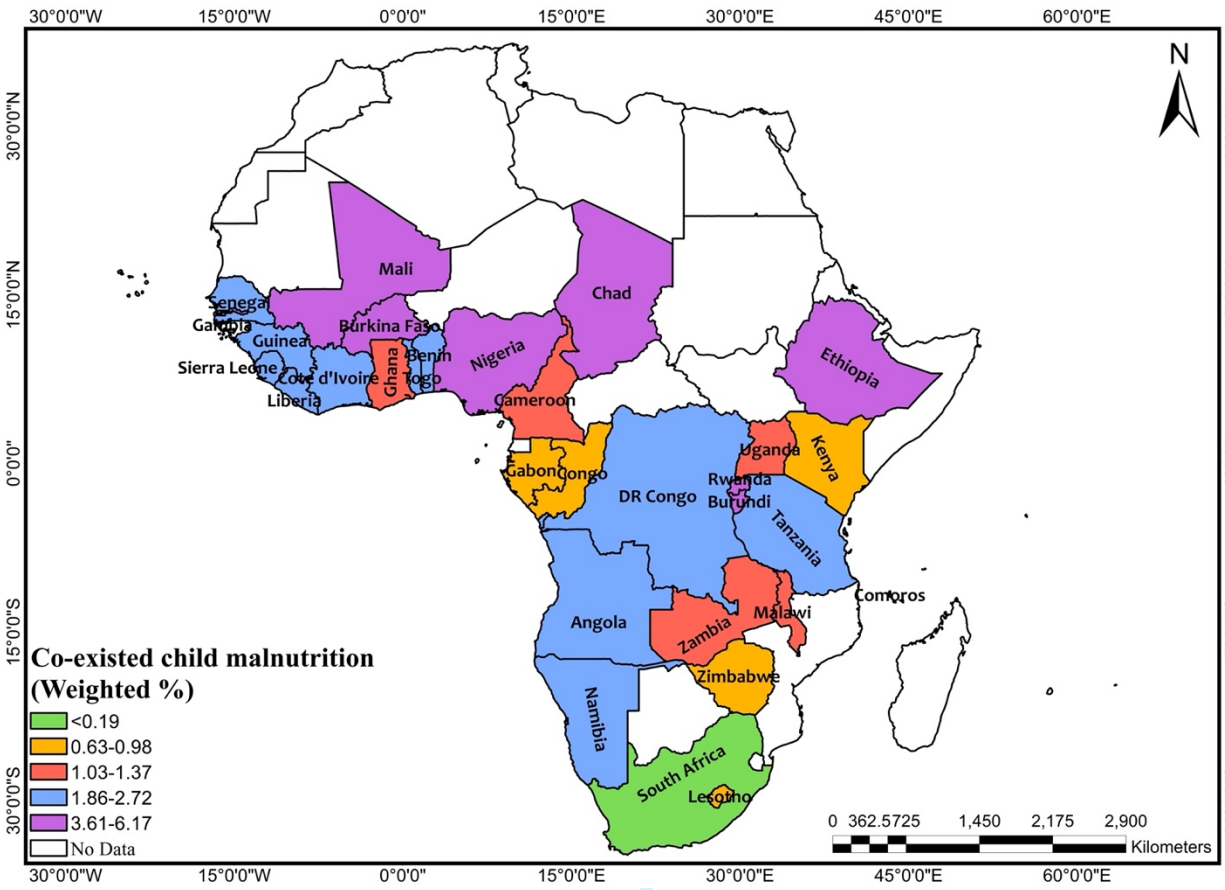

Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

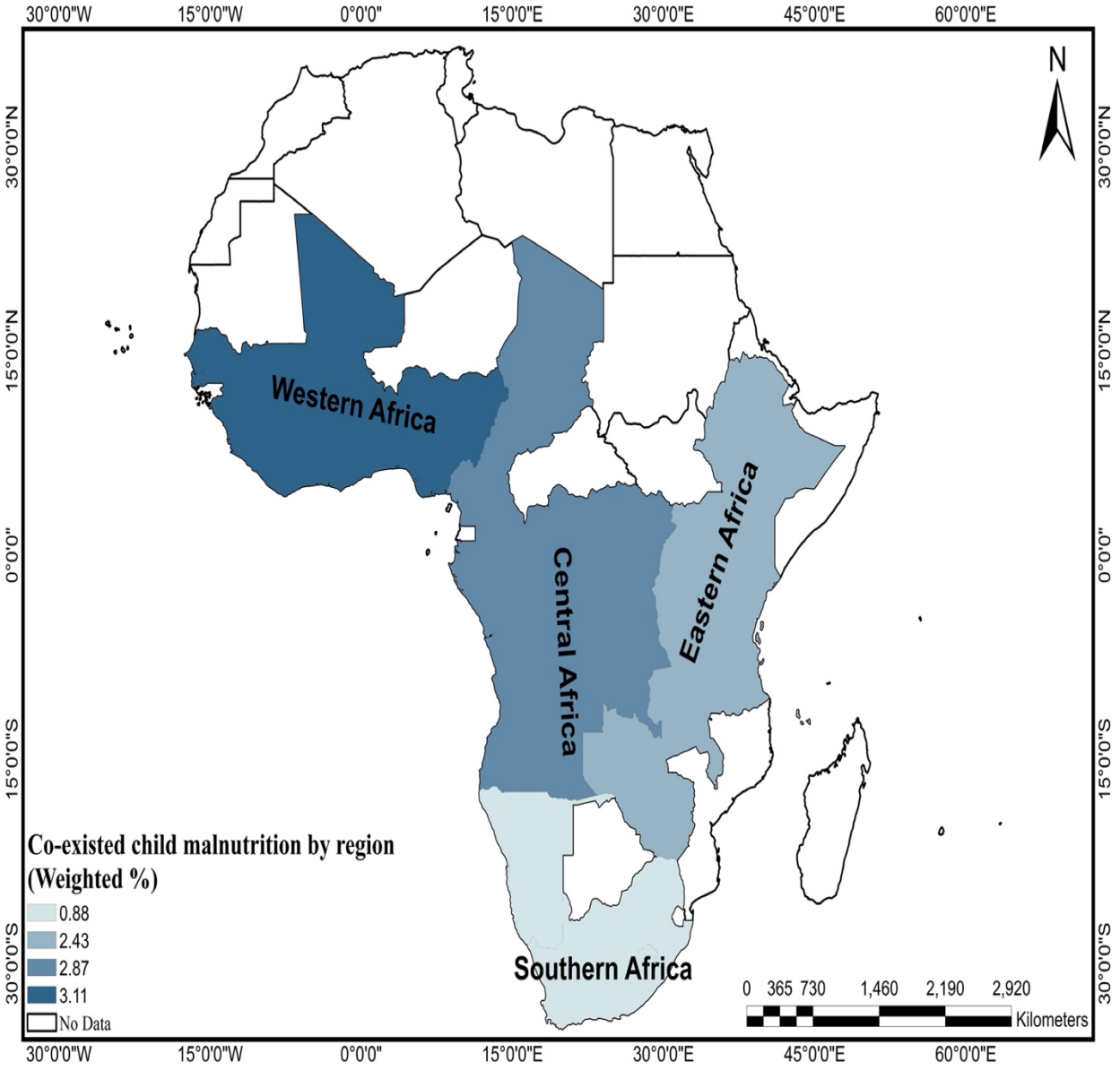

Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

Supplementary Tables

Appendix 1: Distribution of sample by country

Country	Survey year	n	%
Angola	2015-16	7,318	5.74
Benin	2017-18	15,473	12.14
Burkina Faso	2010	8,908	6.99
Burundi	2016-17	4,172	3.27
Cameroon	2018	2,911	2.28
Chad	2014-2015	5,999	4.71
Comoros	2012	1,320	1.03
Congo	2013	2,609	2.05
Cote d'Ivoire	2011-12	2,174	1.71
Congo DR	2013-14	4,806	3.77
Ethiopia	2016	6,573	5.16
Gabon	2012	1,960	1.54
Gambia	2013	743	0.58
Ghana	2014	1,896	1.49
Guinea	2018	2,237	1.75
Kenya	2014	6,066	4.76
Lesotho	2014	1,012	0.79
Liberia	2013	1,946	1.53
Malawi	2015-16	4,027	3.16
Mali	2018	5,653	4.43
Namibia	2013	905	0.71
Nigeria	2018	7,379	5.79
Rwanda	2014-15	4,408	3.46
Senegal	2010-11	1,944	1.52
Sierra Leone	2019	2,689	2.11
South Africa	2016	855	0.67
Tanzania	2015-16	6,061	4.75
Togo	2013-14	2,220	1.74
Uganda	2016	2,891	2.27
Zambia	2018	6,347	4.98
Zimbabwe	2015	3,987	3.13

Appendix 2: Multicollinearity diagnosis				
Variable	VIF	SQRT VIF	Tolerance	R-Squared
Age of child	1.05	1.02	0.9547	0.0453
Sex of child	1.01	1	0.9948	0.0052
Birth order	1.36	1.17	0.7366	0.2634
Perceived size at birth	1.02	1.01	0.9798	0.0202
Age at child birth	1.22	1.1	0.8224	0.1776
Educational attainment	1.51	1.23	0.664	0.336
Working status	1.07	1.03	0.9357	0.0643
Antenatal visits during pregnancy	1.25	1.12	0.7976	0.2024
Postnatal check within 2 months	1.1	1.05	0.9098	0.0902
Place of delivery	1.31	1.15	0.7617	0.2383
Wealth status	1.8	1.34	0.5554	0.4446
Age of household head	1.05	1.02	0.9546	0.0454
Sex of household head	1.03	1.02	0.9702	0.0298
Access to media (tv/radio/newspaper)	1.26	1.12	0.7913	0.2087
Access to electricity	1.71	1.31	0.5837	0.4163
Type of toilet facility	1.35	1.16	0.7404	0.2596
Source of drinking water	1.09	1.04	0.9191	0.0809
Type of cooking fuel	1.31	1.14	0.7653	0.2347
Urbanicity	1.58	1.26	0.6319	0.3681
Country	1.17	1.08	0.8579	0.1421
Mean VIF	1.26			

Appendix 3: **Country-level risk of co-existence of stunting, wasting, and underweight**

	Base outcome (Ref: Normal)					
	Single and two dimensions			Co-existence of three-dimensions		
	RRR	95% CI		RRR	95% CI	
Country (Ref: Angola)						
Benin	0.651***	0.598	0.708	0.625***	0.489	0.798
Burkina Faso	0.952	0.866	1.046	1.946***	1.526	2.481
Burundi	1.580***	1.424	1.753	2.049***	1.545	2.718
Cameroon	0.669***	0.593	0.756	0.398***	0.261	0.609
Chad	0.910	0.823	1.007	1.505**	1.184	1.913
Comoros	0.883	0.745	1.046	0.656	0.378	1.138
Congo	0.674***	0.580	0.783	0.472**	0.279	0.800
Cote d'Ivoire	0.734***	0.638	0.844	0.739	0.492	1.109
DR Congo	1.229***	1.100	1.373	1.351	0.988	1.847
Ethiopia	0.810***	0.726	0.904	0.813	0.604	1.095
Gabon	0.495***	0.415	0.59	0.319**	0.128	0.796
Gambia	0.732**	0.603	0.889	1.001	0.618	1.620
Ghana	0.453***	0.386	0.531	0.545**	0.346	0.857
Guinea	0.798***	0.705	0.904	0.726	0.509	1.036
Kenya	0.553***	0.498	0.615	0.321***	0.230	0.449
Lesotho	0.777**	0.654	0.924	0.369***	0.177	0.772
Liberia	0.658***	0.565	0.768	0.776	0.484	1.243
Malawi	0.794***	0.708	0.889	0.447***	0.291	0.687
Mali	0.600***	0.541	0.664	1.006	0.769	1.316
Namibia	0.680***	0.568	0.815	0.849	0.505	1.426
Nigeria	0.953	0.868	1.046	1.527**	1.183	1.972
Rwanda	1.059	0.954	1.176	1.991***	1.541	2.571
Senegal	0.660***	0.572	0.761	0.643*	0.434	0.952
Sierra Leone	0.641***	0.567	0.725	0.656*	0.447	0.963
South Africa	0.788*	0.634	0.979	0.108***	0.033	0.352
Tanzania	0.772***	0.699	0.851	0.699**	0.512	0.954
Togo	0.557***	0.490	0.633	0.838	0.590	1.190
Uganda	0.627***	0.556	0.708	0.421***	0.278	0.637
Zambia	0.904*	0.818	0.998	0.519***	0.366	0.736
Zimbabwe	0.693***	0.620	0.775	0.344***	0.214	0.554

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

	Item No.	Recommendation	Page No.	Relevant text from manuscript
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	
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5	
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	5	
		(*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	6	
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	*5-6*	
Bias	9	Describe any efforts to address potential sources of bias	6	
Study size	10	Explain how the study size was arrived at	5	

Continued on next page

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	7
		(*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	N/A
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	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(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	*N/A*
		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	
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	6-10
		(*b*) Report category boundaries when continuous variables were categorized	6-10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A

Continued on next page

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	8
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	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
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	12

*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.